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FINAL

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)
BACKGROUND DOCUMENT FOR
K087

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EXECUTIVE SUMMARY

BDAT Treatment Standards for K087

Pursuant to the Hazardous and Solid Waste Amendments (HSWA) enacted on November 8, 1984, the Environmental Protection Agency is establishing best demonstrated available technology (BDAT) treatment standards for the listed waste identified in 40 CFR 261.32 as K087. Compliance with these BDAT treatment standards is a prerequisite for placement of the waste in units designated as land disposal units according to 40 CFR Part 268. These treatment standards become effective as of August 8, 1988.

This background document provides the Agency's rationale and technical support for selecting the constituents to be regulated in K087 waste and for developing treatment standards for those regulated constituents. The document also provides waste characterization information that serves as a basis for determining whether treatment variances may be warranted. EPA may grant a treatment variance in cases where the Agency determines that the waste in question is more difficult to treat than the waste upon which the treatment standards have been established.

The introductory section, which appears verbatim in all the First Third background documents, summarizes the Agency's legal authority and promulgated methodology for establishing treatment standards and discusses the petition process necessary for requesting a variance from the treatment standards. The remainder of the document presents waste-specific information--the number and locations of facilities affected by the land disposal restrictions for K087 waste, the waste generating process, waste characterization data, the technologies used to treat the waste (or similar wastes), and available performance data, including data on which the treatment standards are based. The document also explains EPA's determination of BDAT, selection of constituents to be regulated, and calculation of treatment standards.

K087 waste is decanter tank tar sludge from coking operations. The Agency estimates that 36 facilities in the coking industry potentially generate K087 waste. These facilities fall under the Standard Industrial Classification (SIC) Code 3312.

The Agency is regulating nine organic constituents and one metal constituent in both nonwastewater and wastewater forms of K087 waste. (For the purpose of determining the applicability of the BDAT treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Wastes not meeting this definition must comply with the treatment standards for nonwastewaters.) The treatment standards for the organic constituents in both nonwastewater and wastewater are based on performance data from rotary kiln incineration. For the metal constituent, the treatment standards for wastewater are based on performance data from chemical precipitation followed by sludge filtration, while the treatment standards for nonwastewater are based on performance data from stabilization.

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* The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by method 209C (Total Suspended Solids Dried at 103-105°C) in Standard Methods for the Examination of Water and Wastewater, Sixteenth Edition.

The following table lists the specific BDAT treatment standards for K087 nonwastewater and wastewater. For the BDAT list organic constituents, treatment standards reflect the total constituent concentration. For the BDAT list metal constituents, treatment standards in the nonwastewater reflect the concentration of constituents in the leachate from the Toxicity Characteristic Leaching Procedure (TCLP) and treatment standards in the wastewater reflect the total constituent concentration. The units for the total constituent concentration are mg/kg (parts per million on a weight-by-weight basis) for the nonwastewater and mg/l (parts per million on a weight-by-volume basis) for the wastewater. The units for the leachate concentration are mg/l. Note that if the concentrations of the regulated constituents in the waste, as generated, are lower than or equal to the treatment standards, then treatment is not required prior to land disposal.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix B of this background document.

BDAT Treatment Standards for K087

Constituent	Maximum for any single grab sample		
	Nonwastewater		Wastewater
	Total concentration (mg/kg)	TCLP leachate concentration (mg/l)	Total concentration (mg/l)
Volatile Organics			
Benzene	0.071	NA	0.014
Toluene	0.65	NA	0.008
Xylenes	0.070	NA	0.014
Semivolatile Organics			
Acenaphthalene	3.4	NA	0.028
Chrysene	3.4	NA	0.028
Fluoranthene	3.4	NA	0.028
Indeno(1,2,3-cd)pyrene	3.4	NA	0.028
Naphthalene	3.4	NA	0.028
Phenanthrene	3.4	NA	0.028
Metals			
Lead	NA	0.51	0.037

NA = Not applicable.

1. INTRODUCTION

This section of the background document presents a summary of the legal authority pursuant to which the best demonstrated available technology (BDAT) treatment standards were developed, a summary of EPA's promulgated methodology for developing the BDAT treatment standards, and, finally, a discussion of the petition process that should be followed to request a variance from the BDAT treatment standards.

1.1 Legal Background

1.1.1 Requirements Under HSWA

The Hazardous and Solid Waste Amendments of 1984 (HSWA), which were enacted on November 8, 1984, and which amended the Resource Conservation and Recovery Act of 1976 (RCRA), impose substantial new responsibilities on those who handle hazardous waste. In particular, the amendments require the Agency to promulgate regulations that restrict the land disposal of untreated hazardous wastes. In its enactment of HSWA, Congress stated explicitly that "reliance on land disposal should be minimized or eliminated, and land disposal, particularly landfill and surface impoundment, should be the least favored method for managing hazardous wastes" (RCRA section 1002(b)(7), 42 U.S.C. 6901(b)(7)).

One part of the amendments specifies dates on which particular groups of untreated hazardous wastes will be prohibited from land disposal unless "it has been demonstrated to the Administrator, to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit or injection zone for as long as the wastes remain hazardous" (RCRA section 3004(d)(1), (e)(1), (g)(5), 42 U.S.C. 6924 (d)(1), (e)(1), (g)(5)).

For the purpose of the restrictions, HSWA defines land disposal "to include, but not be limited to, any placement of . . . hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, salt bed formation, or underground mine or cave" (RCRA section 3004(k), 42 U.S.C. 6924(k)). Although HSWA defines land disposal to include injection wells, such disposal of solvents, dioxins, and certain other wastes, known as the California List wastes, is covered on a separate schedule (RCRA section 3004(f)(2), 42 U.S.C. 6924 (f)(2)). This schedule requires that EPA develop land disposal restrictions for deep well injection by August 8, 1988.

The amendments also require the Agency to set "levels or methods of treatment, if any, which substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste so that short-term and long-term threats to human health and the environment are minimized" (RCRA section 3004(m)(1), 42 U.S.C. 6924 (m)(1)). Wastes that satisfy such levels or methods of treatment established by EPA, i.e., treatment standards, are not prohibited from being land disposed.

In setting treatment standards for listed or characteristic wastes, EPA may establish different standards for particular wastes within a single waste code with differing treatability characteristics. One such characteristic is the physical form of the waste. This frequently leads to different standards for wastewaters and nonwastewaters. Alternatively, EPA can establish a treatment standard that is applicable to more than one waste code when, in EPA's judgment, a particular constituent present in the wastes can be treated to the same concentration in all the wastes.

In those instances where a generator can demonstrate that the standard promulgated for the generator's waste cannot be achieved, the amendments allow the Agency to grant a variance from a treatment standard by revising the treatment standard for that particular waste through rulemaking procedures. (A further discussion of treatment variances is provided in Section 1.3.)

The land disposal restrictions are effective when promulgated unless the Administrator grants a national variance and establishes a different date (not to exceed 2 years beyond the statutory deadline) based on "the earliest date on which adequate alternative treatment, recovery, or disposal capacity which protects human health and the environment will be available" (RCRA section 3004(h)(2), 42 U.S.C. 6924 (h)(2)).

If EPA fails to set treatment standards by the statutory deadline for any hazardous waste in the First Third or Second Third waste groups (see Section 1.1.2), the waste may not be disposed in a landfill or surface impoundment unless the facility is in compliance with the minimum technological requirements specified in section 3004(o) of RCRA. In addition, prior to disposal, the generator must certify to the Administrator that the availability of treatment capacity has been investigated, and it has been determined that disposal in a landfill or surface impoundment is the only practical alternative to treatment currently available to the generator. This restriction on the use of landfills and surface impoundments applies until EPA sets treatment standards for the waste or until May 8, 1990, whichever is sooner. If the Agency fails to set treatment standards for any ranked hazardous waste by May 8, 1990, the waste is automatically prohibited from land disposal unless the waste is placed in a land disposal unit that is the subject of a successful "no migration" demonstration (RCRA section 3004(g), 42 U.S.C. 6924(g)). "No migration" demonstrations are based on case-specific petitions that show there will be no migration of hazardous constituents from the unit for as long as the waste remains hazardous.

1.1.2 Schedule for Developing Restrictions

Under section 3004(g) of RCRA, EPA was required to establish a schedule for developing treatment standards for all wastes that the Agency had listed as hazardous by November 8, 1984. Section 3004(g) required that this schedule consider the intrinsic hazards and volumes associated with each of these wastes. The statute required EPA to set treatment standards according to the following schedule:

1. Solvent and dioxin wastes by November 8, 1986;
2. The "California List" wastes by July 8, 1987;
3. At least one-third of all listed hazardous wastes by August 8, 1988 (First Third);

4. At least two-thirds of all listed hazardous wastes by June 8, 1989 (Second Third); and
5. All remaining listed hazardous wastes and all hazardous wastes identified as of November 8, 1984, by one or more of the characteristics defined in 40 CFR Part 261 by May 8, 1990 (Third Third).

The statute specifically identified the solvent wastes as those covered under waste codes F001, F002, F003, F004, and F005; it identified the dioxin-containing hazardous wastes as those covered under waste codes F020, F021, F022, and F023.

Wastes collectively known as the California List wastes, defined under section 3004(d) of HSWA, are liquid hazardous wastes containing metals, free cyanides, PCBs, corrosives (i.e., a pH less than or equal to 2.0), and any liquid or nonliquid hazardous waste containing halogenated organic compounds (HOCs) above 0.1 percent by weight. Rules for the California List were proposed on December 11, 1986, and final rules for PCBs, corrosives, and HOC-containing wastes were established August 12, 1987. In that rule, EPA elected not to establish treatment standards for metals. Therefore, the statutory limits became effective.

On May 28, 1986, EPA published a final rule (51 FR 19300) that delineated the specific waste codes that would be addressed by the First Third, Second Third, and Third Third land disposal restriction rules. This schedule is incorporated into 40 CFR 268.10, 268.11, and 268.12.

1.2 Summary of Promulgated BDAT Methodology

In a November 7, 1986, rulemaking, EPA promulgated a technology-based approach to establishing treatment standards under section 3004(m).

Congress indicated in the legislative history accompanying the HSWA that "[t]he requisite levels of [sic] methods of treatment established by the Agency should be the best that has been demonstrated to be achievable," noting that the intent is "to require utilization of available technology" and not a "process which contemplates technology-forcing standards" (Vol. 130 Cong. Rec. S9178 (daily ed., July 25, 1984)). EPA has interpreted this legislative history as suggesting that Congress considered the requirement under section 3004(m) to be met by application of the best demonstrated and achievable (i.e., available) technology prior to land disposal of wastes or treatment residuals. Accordingly, EPA's treatment standards are generally based on the performance of the best demonstrated available technology (BDAT) identified for treatment of the hazardous constituents. This approach involves the identification of potential treatment systems, the determination of whether they are demonstrated and available, and the collection of treatment data from well-designed and well-operated systems.

The treatment standards, according to the statute, can represent levels or methods of treatment, if any, that substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents. Wherever possible, the Agency prefers to establish BDAT treatment standards as "levels" of treatment (i.e., performance standards), rather than to require the use of specific treatment "methods." EPA believes that concentration-based treatment levels offer the regulated community greater flexibility to develop and implement compliance strategies, as well as an incentive to develop innovative technologies.

1.2.1 Waste Treatability Group

In developing the treatment standards, EPA first characterizes the waste(s). As necessary, EPA may establish treatability groups for wastes having similar physical and chemical properties. That is, if EPA believes that hazardous constituents in wastes represented by different waste codes could be treated to similar concentrations using identical technologies, the Agency combines the wastes into one treatability group. EPA generally considers wastes to be similar when they are both generated from the same industry and from similar processing stages. In addition, EPA may combine two or more separate wastes into the same treatability group when data are available showing that the waste characteristics affecting performance are similar or that one of the wastes in the group, the waste from which treatment standards are to be developed, is expected to be most difficult to treat.

Once the treatability groups have been established, EPA collects and analyzes data on identified technologies used to treat the wastes in each treatability group. The technologies evaluated must be demonstrated on the waste or a similar waste and must be available for use.

1.2.2 Demonstrated and Available Treatment Technologies

Consistent with legislative history, EPA considers demonstrated technologies to be those that are currently used on a full-scale basis to treat the waste of interest or a waste judged to be similar (see 51 FR 40588, November 7, 1986). EPA also will consider as demonstrated treatment those technologies used to separate or otherwise process chemicals and other materials on a full-scale basis. Some of these technologies clearly are applicable to waste treatment, since the wastes are similar to raw materials processed in industrial applications.

For most of the waste treatability groups for which EPA will promulgate treatment standards, EPA will identify demonstrated technologies either through review of literature related to current waste treatment practices or on the basis of information provided by specific facilities currently treating the waste or similar wastes.

In cases where the Agency does not identify any facilities treating wastes represented by a particular waste treatability group, EPA may transfer a finding of demonstrated treatment. To do this, EPA will compare the parameters affecting treatment selection for the waste treatability group of interest to other wastes for which demonstrated technologies already have been determined. (The parameters affecting treatment selection and their use for this waste are described in Section 3.2 of this document.) If the parameters affecting treatment selection are similar, then the Agency will consider the treatment technology also to be demonstrated for the waste of interest. For example, EPA considers rotary kiln incineration to be a demonstrated technology for many waste codes containing hazardous organic constituents, high total organic content, and high filterable solids content, regardless of whether any facility is currently treating these wastes. The basis for this determination is data found in literature and data generated by EPA confirming the use of rotary kiln incineration on wastes having the above characteristics.

If no full-scale treatment or recovery operations are identified for a waste or wastes with similar physical or chemical characteristics that affect treatment selection, the Agency will be unable to identify any demonstrated treatment technologies for the waste, and, accordingly, the waste will be prohibited from land disposal (unless handled in accordance with the exemption and variance provisions of the rule). The Agency is, however, committed to establishing treatment standards as soon as new or improved treatment processes are demonstrated (and available).

Operations only available at research facilities, pilot- and bench-scale operations, will not be considered in identifying demonstrated treatment technologies for a waste. Nevertheless, EPA may use data generated at research facilities in assessing the performance of demonstrated technologies.

As discussed earlier, Congress intended that technologies used to establish treatment standards under section 3004(m) be not only "demonstrated," but also "available." To decide whether demonstrated technologies may be considered "available," the Agency determines whether they (1) are commercially available and (2) substantially diminish the toxicity of the waste or substantially reduce the likelihood of migration of hazardous constituents from the waste. These criteria are discussed below.

1. Commercially available treatment. If the demonstrated treatment technology is a proprietary or patented process that is not generally available, EPA will not consider the technology in its determination of the treatment standards. EPA will consider proprietary or patented processes available if it determines that the treatment method can be purchased or licensed from the proprietor or is a commercially available treatment. The services of the commercial facility offering this technology often can be purchased even if the technology itself cannot be purchased.

2. Substantial treatment. To be considered "available," a demonstrated treatment technology must "substantially diminish the toxicity" of the waste or "substantially reduce the likelihood of migration of hazardous constituents" from the waste in accordance with section 3004(m). By requiring that substantial treatment be achieved in order to set a treatment standard, the statute ensures that all wastes are adequately treated before being placed in or on the land and ensures that the Agency does not require a treatment method that provides little or no environmental benefit. Treatment will always be deemed substantial if it results in nondetectable levels of the hazardous constituents of concern (provided the nondetectable levels are low relative to the concentrations in the untreated waste). If nondetectable levels are not achieved, then a determination of substantial treatment will be made on a case-by-case basis. This approach is necessary because of the difficulty of establishing a meaningful guideline that can be applied broadly to the many wastes and technologies to be considered. EPA will consider the following factors in an effort to evaluate whether a technology provides substantial treatment on a case-by-case basis:

   - Number and types of constituents treated;
   - Performance (concentration of the constituents in the treatment residuals); and
   - Percent of constituents removed.

EPA will only set treatment standards based on a technology that meets both availability criteria. Thus, the decision to classify a technology as "unavailable" will have a direct impact on the treatment standard. If the best demonstrated technology is unavailable, the treatment standards will be based on the next best demonstrated treatment technology determined to be available. To the extent that the resulting treatment standards are less stringent, greater concentrations of hazardous constituents in the treatment residuals could be placed in land disposal units.

There also may be circumstances in which EPA concludes that for a given waste none of the demonstrated treatment technologies are "available" for purposes of establishing the 3004(m) treatment performance standards. Subsequently, these wastes will be prohibited from continued placement in or on the land unless managed in accordance with applicable exemptions and variance provisions. The Agency is, however, committed to establishing new treatment standards as soon as new or improved treatment processes become available.

1.2.3 Collection of Performance Data

Performance data on the demonstrated available technologies are evaluated by the Agency to determine whether the data are representative of well-designed and well-operated treatment systems. Only data from well-designed and well-operated systems are considered in determining BDAT. The data evaluation includes data already collected directly by

EPA and/or data provided by industry. In those instances where additional data are needed to supplement existing information, EPA collects additional data through a sampling and analysis program. The principal elements of this data collection program are: (1) the identification of facilities for site visits, (2) the engineering site visit, (3) the sampling and analysis plan, (4) the sampling visit, and (5) the onsite engineering report.

(1) Identification of facilities for site visits. To identify facilities that generate and/or treat the waste of concern, EPA uses a number of information sources. These include Stanford Research Institute's Directory of Chemical Producers; EPA's Hazardous Waste Data Management System (HWDMS); the 1986 Treatment, Storage, Disposal Facility (TSDF) National Screening Survey; and EPA's Industry Studies Data Base. In addition, EPA contacts trade associations to inform them that the Agency is considering visits to facilities in their industry and to solicit their assistance in identifying facilities for EPA to consider in its treatment sampling program.

After identifying facilities that treat the waste, EPA uses this hierarchy to select sites for engineering visits: (1) generators treating single wastes on site; (2) generators treating multiple wastes together on site; (3) commercial treatment, storage, and disposal facilities (TSDFs); and (4) EPA in-house treatment. This hierarchy is based on two concepts: (1) to the extent possible, EPA should develop treatment standards from data produced by treatment facilities handling only a single waste, and (2) facilities that routinely treat a specific waste have had the best opportunity to optimize design parameters. Although excellent treatment can occur at many facilities that are not high in this hierarchy, EPA has adopted this approach to avoid, when possible, ambiguities related to the mixing of wastes before and during treatment.

When possible, the Agency will evaluate treatment technologies using full-scale treatment systems. If performance data from properly designed and operated full-scale systems treating a particular waste or a waste judged to be similar are not available, EPA may use data from research facility operations. Whenever research facility data are used, EPA will explain in the preamble and background document why such data were used and will request comments on the use of such data.

Although EPA's data bases provide information on treatment for individual wastes, the data bases rarely provide data that support the selection of one facility for sampling over another. In cases where several treatment sites appear to fall into the same level of the hierarchy, EPA selects sites for visits strictly on the basis of which facility could most expeditiously be visited and later sampled if justified by the engineering visit.

(2) Engineering site visit. Once a treatment facility has been selected, an engineering site visit is made to confirm that a candidate for sampling meets EPA's criteria for a well-designed facility and to

ensure that the necessary sampling points can be accessed to determine operating parameters and treatment effectiveness. During the visit, EPA also confirms that the facility appears to be well operated, although the actual operation of the treatment system during sampling is the basis for EPA's decisions regarding proper operation of the treatment unit. In general, the Agency considers a well-designed facility to be one that contains the unit operations necessary to treat the various hazardous constituents of the waste, as well as to control other nonhazardous materials in the waste that may affect treatment performance.

In addition to ensuring that a system is reasonably well designed, the engineering visit examines whether the facility has a way to measure the operating parameters that affect performance of the treatment system during the waste treatment period. For example, EPA may choose not to sample a treatment system that operates in a continuous mode, for which an important operating parameter cannot be continuously recorded. In such systems, instrumentation is important in determining whether the treatment system is operating at design values during the waste treatment period.

(3) Sampling and analysis plan. If after the engineering site visit the Agency decides to sample a particular plant, the Agency will then develop a site-specific sampling and analysis plan (SAP) according to the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011. In brief, the SAP discusses where the Agency plans to sample, how the samples will be taken, the frequency

of sampling, the constituents to be analyzed and the method of analysis, operational parameters to be obtained, and specific laboratory quality control checks on the analytical results.

The Agency will generally produce a draft of the site-specific SAP within 2 to 3 weeks of the engineering visit. The draft of the SAP is then sent to the plant for review and comment. With few exceptions, the draft SAP should be a confirmation of data collection activities discussed with the plant personnel during the engineering site visit. EPA encourages plant personnel to recommend any modifications to the SAP that they believe will improve the quality of the data.

It is important to note that sampling of a plant by EPA does not mean that the data will be used in the development of BDAT treatment standards. EPA's final decision on whether to use data from a sampled plant depends on the actual analysis of the waste being treated and on the operating conditions at the time of sampling. Although EPA would not plan to sample a facility that was not ostensibly well designed and well operated, there is no way to ensure that at the time of the sampling the facility will not experience operating problems. Additionally, EPA statistically compares its test data to suitable industry-provided data, where available, in its determination of what data to use in developing treatment standards. The methodology for comparing data is presented later in this section.

(Note: Facilities wishing to submit data for consideration in the development of BDAT standards should, to the extent possible, provide sampling information similar to that acquired by EPA. Such facilities should review the Generic Quality Assurance Project Plan for the Land Disposal Restrictions Program ("BDAT"), which delineates all of the quality control and quality assurance measures associated with sampling and analysis. Quality assurance and quality control procedures are summarized in Section 1.2.6 of this document.)

(4) Sampling visit. The purpose of the sampling visit is to collect samples that characterize the performance of the treatment system and to document the operating conditions that existed during the waste treatment period. At a minimum, the Agency attempts to collect sufficient samples of the untreated waste and solid and liquid treatment residuals so that variability in the treatment process can be accounted for in the development of the treatment standards. To the extent practicable, and within safety constraints, EPA or its contractors collect all samples and ensure that chain-of-custody procedures are conducted so that the integrity of the data is maintained.

In general, the samples collected during the sampling visit will have already been specified in the SAP. In some instances, however, EPA will not be able to collect all planned samples because of changes in the facility operation or plant upsets; EPA will explain any such deviations from the SAP in its follow-up onsite engineering report.

(5) Onsite engineering report. EPA summarizes all its data collection activities and associated analytical results for testing at a facility in a report referred to as the onsite engineering report (OER). This report characterizes the waste(s) treated, the treated residual concentrations, the design and operating data, and all analytical results including methods used and accuracy results. This report also describes any deviations from EPA's suggested analytical methods for hazardous wastes that appear in Test Methods for Evaluating Solid Waste, SW-846, Third Edition, November 1986.

After the OER is completed, the report is submitted to the waste generator and/or treater for review. This review provides a final opportunity for claiming any information contained in the report as confidential. Following the review and incorporation of comments, as appropriate, the report is made available to the public with the exception of any material claimed as confidential.

1.2.4 Hazardous Constituents Considered and Selected for Regulation

(1) Development of BDAT list. The list of hazardous constituents within the waste codes that are targeted for treatment is referred to by the Agency as the BDAT constituent list. This list, provided as Table 1-1, is derived from the constituents presented in 40 CFR Part 261, Appendices VII and VIII, as well as several ignitable constituents used as the basis of listing wastes as F003 and F005. These sources provide a

Table 1-1 BDAT Constituent List

BDAT reference no.	Constituent	CAS no.
	Volatile organics	
222.	Acetone	67-64-1
1.	Acetonitrile	75-05-8
2.	Acrolein	107-02-8
3.	Acrylonitrile	107-13-1
4.	Benzene	71-43-2
5.	Bromodichloromethane	75-27-4
6.	Bromomethane	74-83-9
223.	n-Butyl alcohol	71-36-3
7.	Carbon tetrachloride	56-23-5
8.	Carbon disulfide	75-15-0
9.	Chlorobenzene	108-90-7
10.	2-Chloro-1,3-butadiene	126-99-8
11.	Chlorodibromomethane	124-48-1
12.	Chloroethane	75-00-3
13.	2-Chloroethyl vinyl ether	110-75-8
14.	Chloroform	67-66-3
15.	Chloromethane	74-87-3
16.	3-Chloropropene	107-05-1
17.	1,2-Dibromo-3-chloropropane	96-12-8
18.	1,2-Dibromoethane	106-93-4
19.	Dibromomethane	74-95-3
20.	trans-1,4-Dichloro-2-butene	110-57-6
21.	Dichlorodifluoromethane	75-71-8
22.	1,1-Dichloroethane	75-34-3
23.	1,2-Dichloroethane	107-06-2
24.	1,1-Dichloroethylene	75-35-4
25.	trans-1,2-Dichloroethene	156-60-5
26.	1,2-Dichloropropane	78-87-5
27.	trans-1,3-Dichloropropene	10061-02-6
28.	cis-1,3-Dichloropropene	10061-01-5
29.	1,4-Dioxane	123-91-1
224.	2-Ethoxyethanol	110-80-5
225.	Ethyl acetate	141-78-6
226.	Ethyl benzene	100-41-4
30.	Ethyl cyanide	107-12-0
227.	Ethyl ether	60-29-7
31.	Ethyl methacrylate	97-63-2
214.	Ethylene oxide	75-21-8
32.	Iodomethane	74-88-4
33.	Isobutyl alcohol	78-83-1
228.	Methanol	67-56-1
34.	Methyl ethyl ketone	78-93-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Volatile organics (continued)	
229.	Methyl isobutyl ketone	108-10-1
35.	Methyl methacrylate	80-62-6
37.	Methacrylonitrile	126-98-7
38.	Methylene chloride	75-09-2
230.	2-Nitropropane	79-46-9
39.	Pyridine	110-86-1
40.	1,1,1,2-Tetrachloroethane	630-20-6
41.	1,1,2,2-Tetrachloroethane	79-34-6
42.	Tetrachloroethene	127-18-4
43.	Toluene	108-88-3
44.	Tribromomethane	75-25-2
45.	1,1,1-Trichloroethane	71-55-6
46.	1,1,2-Trichloroethane	79-00-5
47.	Trichloroethene	79-01-6
48.	Trichloromonofluoromethane	75-69-4
49.	1,2,3-Trichloropropane	96-18-4
231.	1,1,2-Trichloro 1,2,2-trifluoroethane	76-13-1
50.	Vinyl chloride	75-01-4
215.	1,2-Xylene	97-47-6
216.	1,3-Xylene	108-38-3
217.	1,4 Xylene	106-44-5
	Semivolatile organics	
51.	Acenaphthalene	208-96-8
52.	Acenaphthene	83-32-9
53.	Acetophenone	96-86-2
54.	2-Acetylaminofluorene	53-96-3
55.	4-Aminobiphenyl	92-67-1
56.	Aniline	62-53-3
57.	Anthracene	120-12-7
58.	Aramite	140-57-8
59.	Benz(a)anthracene	56-55-3
218.	Benzal chloride	98-87-3
60.	Benzenethiol	108-98-5
61.	Deleted	
62.	Benzo(a)pyrene	50-32-8
63.	Benzo(b)fluoranthene	205-99-2
64.	Benzo(ghi)perylene	191-24-2
65.	Benzo(k)fluoranthene	207-08-9
66.	p-Benzoquinone	106-51-4

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
67.	Bis(2-chloroethoxy)methane	111-91-1
68.	Bis(2-chloroethyl)ether	111-44-4
69.	Bis(2-chloroisopropyl)ether	39638-32-9
70.	Bis(2-ethylhexyl)phthalate	117-81-7
71.	4-Bromophenyl phenyl ether	101-55-3
72.	Butyl benzyl phthalate	85-68-7
73.	2-sec-Butyl-4,6-dinitrophenol	88-85-7
74.	p-Chloroaniline	106-47-8
75.	Chlorobenzilate	510-15-6
76.	p-Chloro-m-cresol	59-50-7
77.	2-Chloronaphthalene	91-58-7
78.	2-Chlorophenol	95-57-8
79.	3-Chloropropionitrile	542-76-7
80.	Chrysene	218-01-9
81.	ortho-Cresol	95-48-7
82.	para-Cresol	106-44-5
232.	Cyclohexanone	108-94-1
83.	Dibenz(a,h)anthracene	53-70-3
84.	Dibenzo(a,e)pyrene	192-65-4
85.	Dibenzo(a,i)pyrene	189-55-9
86.	m-Dichlorobenzene	541-73-1
87.	o-Dichlorobenzene	95-50-1
88.	p-Dichlorobenzene	106-46-7
89.	3,3'-Dichlorobenzidine	91-94-1
90.	2,4-Dichlorophenol	120-83-2
91.	2,6-Dichlorophenol	87-65-0
92.	Diethyl phthalate	84-66-2
93.	3,3'-Dimethoxybenzidine	119-90-4
94.	p-Dimethylaminoazobenzene	60-11-7
95.	3,3'-Dimethylbenzidine	119-93-7
96.	2,4-Dimethylphenol	105-67-9
97.	Dimethyl phthalate	131-11-3
98.	Di-n-butyl phthalate	84-74-2
99.	1,4-Dinitrobenzene	100-25-4
100.	4,6-Dinitro-o-cresol	534-52-1
101.	2,4-Dinitrophenol	51-28-5
102.	2,4-Dinitrotoluene	121-14-2
103.	2,6-Dinitrotoluene	606-20-2
104.	Di-n-octyl phthalate	117-84-0
105.	Di-n-propylnitrosamine	621-64-7
106.	Diphenylamine	122-39-4
219.	Diphenylnitrosamine	86-30-6

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
107.	1,2-Diphenylhydrazine	122-66-7
108.	Fluoranthene	206-44-0
109.	Fluorene	86-73-7
110.	Hexachlorobenzene	118-74-1
111.	Hexachlorobutadiene	87-68-3
112.	Hexachlorocyclopentadiene	77-47-4
113.	Hexachloroethane	67-72-1
114.	Hexachlorophene	70-30-4
115.	Hexachloropropene	1888-71-7
116.	Indeno(1,2,3-cd)pyrene	193-39-5
117.	Isosafrole	120-58-1
118.	Methapyrilene	91-80-5
119.	3-Methylcholanthrene	56-49-5
120.	4,4'-Methylenebis (2-chloroaniline)	101-14-4
36.	Methyl methanesulfonate	66-27-3
121.	Naphthalene	91-20-3
122.	1,4-Naphthoquinone	130-15-4
123.	1-Naphthylamine	134-32-7
124.	2-Naphthylamine	91-59-8
125.	p-Nitroaniline	100-01-6
126.	Nitrobenzene	98-95-3
127.	4-Nitrophenol	100-02-7
128.	N-Nitrosodi-n-butylamine	924-16-3
129.	N-Nitrosodiethylamine	55-18-5
130.	N-Nitrosodimethylamine	62-75-9
131.	N-Nitrosomethylethylamine	10595-95-6
132.	N-Nitrosomorpholine	59-89-2
133.	N-Nitrosopiperidine	100-75-4
134.	N-Nitrosopyrrolidine	930-55-2
135.	5-Nitro-o-toluidine	99-65-8
136.	Pentachlorobenzene	608-93-5
137.	Pentachloroethane	76-01-7
138.	Pentachloronitrobenzene	82-68-8
139.	Pentachlorophenol	87-86-5
140.	Phenacetin	62-44-2
141.	Phenanthrene	85-01-8
142.	Phenol	108-95-2
220.	Phthalic anhydride	85-44-9
143.	2-Picoline	109-06-8
144.	Pronamide	23950-58-5
145.	Pyrene	129-00-0
146.	Resorcinol	108-46-3

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Semivolatile organics (continued)	
147.	Safrole	94-59-7
148.	1,2,4,5-Tetrachlorobenzene	95-94-3
149.	2,3,4,6-Tetrachlorophenol	58-90-2
150.	1,2,4-Trichlorobenzene	120-82-1
151.	2,4,5-Trichlorophenol	95-95-4
152.	2,4,6-Trichlorophenol	88-06-2
153.	Tris(2,3-dibromopropyl) phosphate	126-72-7
	Metals	
154.	Antimony	7440-36-0
155.	Arsenic	7440-38-2
156.	Barium	7440-39-3
157.	Beryllium	7440-41-7
158.	Cadmium	7440-43-9
159.	Chromium (total)	7440-47-3
221.	Chromium (hexavalent)	-
160.	Copper	7440-50-8
161.	Lead	7439-92-1
162.	Mercury	7439-97-6
163.	Nickel	7440-02-0
164.	Selenium	7782-49-2
165.	Silver	7440-22-4
166.	Thallium	7440-28-0
167.	Vanadium	7440-62-2
168.	Zinc	7440-66-6
	Inorganics other than metals	
169.	Cyanide	57-12-5
170.	Fluoride	16964-48-8
171.	Sulfide	8496-25-8
	Organochlorine pesticides	
172.	Aldrin	309-00-2
173.	alpha-BHC	319-84-6
174.	beta-BHC	319-85-7
175.	delta-BHC	319-86-8

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Organochlorine pesticides (continued)	
176.	gamma-BHC	58-89-9
177.	Chlordane	57-74-9
178.	DDD	72-54-8
179.	DDE	72-55-9
180.	DDT	50-29-3
181.	Dieldrin	60-57-1
182.	Endosulfan I	939-98-8
183.	Endosulfan II	33213-6-5
184.	Endrin	72-20-8
185.	Endrin aldehyde	7421-93-4
186.	Heptachlor	76-44-8
187.	Heptachlor epoxide	1024-57-3
188.	Isodrin	465-73-6
189.	Kepone	143-50-0
190.	Methoxyclor	72-43-5
191.	Toxaphene	8001-35-2
	Phenoxyacetic acid herbicides	
192.	2,4-Dichlorophenoxyacetic acid	94-75-7
193.	Silvex	93-72-1
194.	2,4,5-T	93-76-5
	Organophosphorous insecticides	
195.	Disulfoton	298-04-4
196.	Famphur	52 85-7
197.	Methyl parathion	298-00-0
198.	Parathion	56-38-2
199.	Phorate	298-02-2
	PCBs	
200.	Aroclor 1016	12674-11-2
201.	Aroclor 1221	11104 28-2
202.	Aroclor 1232	11141-16-5
203.	Aroclor 1242	53469-21-9
204.	Aroclor 1248	12672-29-6
205.	Aroclor 1254	11097-69-1
206.	Aroclor 1260	11096-82-5

Table 1-1 (Continued)

BDAT reference no.	Constituent	CAS no.
	Dioxins and furans	
207.	Hexachlorodibenzo-p-dioxins	-
208.	Hexachlorodibenzofurans	-
209.	Pentachlorodibenzo-p-dioxins	-
210.	Pentachlorodibenzofurans	-
211.	Tetrachlorodibenzo-p-dioxins	-
212.	Tetrachlorodibenzofurans	-
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6

comprehensive list of hazardous constituents specifically regulated under RCRA. The BDAT list consists of those constituents that can be analyzed using methods published in SW-846, Third Edition.

The initial BDAT constituent list was published in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT") in March 1987. Additional constituents are added to the BDAT constituent list as more key constituents are identified for specific waste codes or as new analytical methods are developed for hazardous constituents. For example, since the list was published in March 1987, 18 additional constituents (hexavalent chromium, xylenes (all three isomers), benzal chloride, phthalic anhydride, ethylene oxide, acetone, n-butyl alcohol, 2-ethoxyethanol, ethyl acetate, ethyl benzene, ethyl ether, methanol, methyl isobutyl ketone, 2-nitropropane, 1,1,2-trichloro-1,2,2-trifluoroethane, and cyclohexanone) have been added to the list.

Chemicals are listed in Appendix VIII if they are shown in scientific studies to have toxic, carcinogenic, mutagenic, or teratogenic effects on humans or other life-forms, and they include such substances as those identified by the Agency's Carcinogen Assessment Group as being carcinogenic. A waste can be listed as a toxic waste on the basis that it contains a constituent in Appendix VIII.

Although Appendix VII, Appendix VIII, and the F003 and F005 ignitables provide a comprehensive list of RCRA-regulated hazardous constituents, not all of the constituents can be analyzed in a complex waste matrix. Therefore, constituents that could not be readily analyzed in an unknown waste matrix were not included on the initial BDAT constituent list. As mentioned above, however, the BDAT constituent list is a continuously growing list that does not preclude the addition of new constituents when analytical methods are developed.

There are five major reasons that constituents were not included on the BDAT constituent list:

1. Constituents are unstable. Based on their chemical structure, some constituents will either decompose in water or will ionize. For example, maleic anhydride will form maleic acid when it comes in contact with water, and copper cyanide will ionize to form copper and cyanide ions. However, EPA may choose to regulate the decomposition or ionization products.

2. EPA-approved or verified analytical methods are not available. Many constituents, such as 1,3,5-trinitrobenzene, are not measured adequately or even detected using any of EPA's analytical methods published in SW-846 Third Edition.

3. The constituent is a member of a chemical group designated in Appendix VIII as not otherwise specified (N.O.S.). Constituents listed as N.O.S., such as chlorinated phenols, are a generic group of some types of chemicals for which a single analytical procedure is not available. The individual members of each such group need to be listed to determine whether the constituents can be analyzed. For each N.O.S. group, all those constituents that can be readily analyzed are included in the BDAT constituent list.

4. Available analytical procedures are not appropriate for a complex waste matrix. Some compounds, such as auramine, can be analyzed as a pure constituent. However, in the presence of other constituents, the recommended analytical method does not positively identify the constituent. The use of high performance liquid chromatography (HPLC) presupposes a high expectation of finding the specific constituents of interest. In using this procedure to screen samples, protocols would have to be developed on a case-specific basis to verify the identity of constituents present in the samples. Therefore, HPLC is usually not an appropriate analytical procedure for complex samples containing unknown constituents.

5. Standards for analytical instrument calibration are not commercially available. For several constituents, such as benz(c)acridine, commercially available standards of a "reasonably" pure grade are not available. The unavailability of a standard was determined by a review of catalogs from specialty chemical manufacturers.

Two constituents (fluoride and sulfide) are not specifically included in Appendices VII and VIII; however, these compounds are included on the BDAT list as indicator constituents for compounds from Appendices VII and VIII such as hydrogen fluoride and hydrogen sulfide, which ionize in water.

The BDAT constituent list presented in Table 1-1 is divided into the following nine groups:

- Volatile organics;
- Semivolatile organics;
- Metals;
- Other inorganics;
- Organochlorine pesticides;
- Phenoxyacetic acid herbicides;
- Organophosphorous insecticides;
- PCBs; and
- Dioxins and furans.

The constituents were placed in these categories based on their chemical properties. The constituents in each group are expected to behave similarly during treatment and are also analyzed, with the exception of the metals and the other inorganics, by using the same analytical methods.

(2) Constituent selection analysis. The constituents that the Agency selects for regulation in each waste are, in general, those found in the untreated wastes at treatable concentrations. For certain waste

codes, the target list for the untreated waste may have been shortened (relative to analyses performed to test treatment technologies) because of the extreme unlikelihood that the constituent will be present.

In selecting constituents for regulation, the first step is to develop of list of potentially regulated constituents by summarizing all the constituents that are present or are likely to be present in the untreated waste at treatable concentrations. A constituent is considered present in a waste if the constituent (1) is detected in the untreated waste above the detection limit, (2) is detected in any of the treated residuals above the detection limit, or (3) is likely to be present based on the Agency's analyses of the waste-generating process. In case (2), the presence of other constituents in the untreated waste may interfere with the quantification of the constituent of concern, making the detection limit relatively high and resulting in a finding of "not detected" when, in fact, the constituent is present in the waste. Thus, the Agency reserves the right to regulate such constituents.

After developing a list of potential constituents for regulation. EPA reviews this list to determine if any of these constituents can be excluded from regulation because they would be controlled by regulation of other constituents on the list. This indicator analysis is done for two reasons: (1) it reduces the analytical cost burdens on the treater and (2) it facilitates implementation of the compliance and enforcement program. EPA's rationale for selection of regulated constituents for this waste code is presented in Section 6 of this background document.

(3) Calculation of standards. The final step in the calculation of the BDAT treatment standard is the multiplication of the average accuracy-corrected treatment value by a factor referred to by the Agency as the variability factor. This calculation takes into account that even well-designed and well-operated treatment systems will experience some fluctuations in performance. EPA expects that fluctuations will result from inherent mechanical limitations in treatment control systems, collection of treated samples, and analysis of these samples. All of the above fluctuations can be expected to occur at well-designed and well-operated treatment facilities. Therefore, setting treatment standards utilizing a variability factor should be viewed not as a relaxing of section 3004(m) requirements, but rather as a function of the normal variability of the treatment processes. A treatment facility will have to be designed to meet the mean achievable treatment performance level to ensure that the performance levels remain within the limits of the treatment standard.

The Agency calculates a variability factor for each constituent of concern within a waste treatability group using the statistical calculation presented in Appendix A. The equation for calculating the variability factor is the same as that used by EPA for the development of numerous regulations in the Effluent Guidelines Program under the Clean Water Act. The variability factor establishes the instantaneous maximum based on the 99th percentile value.

There is an additional step in the calculation of the treatment standards in those instances where the ANOVA analysis shows that more than one technology achieves a level of performance that represents BDAT. In such instances, the BDAT treatment standard for each constituent of concern is calculated by first averaging the mean performance value for each technology and then multiplying that value by the highest variability factor among the technologies considered. This procedure ensures that all the technologies used as the basis for the BDAT treatment standards will achieve full compliance.

1.2.5 Compliance with Performance Standards

Usually the treatment standards reflect performance achieved by the best demonstrated available technology (BDAT). As such, compliance with these numerical standards requires only that the treatment level be achieved prior to land disposal. It does not require the use of any particular treatment technology. While dilution of the waste as a means to comply with the standards is prohibited, wastes that are generated in such a way as to naturally meet the standards can be land disposed without treatment. With the exception of treatment standards that prohibit land disposal or that specify use of certain treatment methods, all established treatment standards are expressed as concentration levels.

EPA is using both the total constituent concentration and the concentration of the constituent in the TCLP extract of the treated waste as a measure of technology performance.

For all organic constituents, EPA is basing the treatment standards on the total constituent concentration found in the treated waste. EPA is using this measurement because most technologies for treatment of organics destroy or remove organics compounds. Accordingly, the best measure of performance would be the total amount of constituent remaining after treatment. (NOTE: EPA's land disposal restrictions for solvent waste codes F001-F005 (51 FR 40572) use the TCLP extract value as a measure of performance. At the time that EPA promulgated the treatment standards for F001-F005, useful data were not available on total constituent concentrations in treated residuals, and, as a result, the TCLP data were considered to be the best measure of performance.)

For all metal constituents, EPA is using both total constituent concentration and/or the TCLP extract concentration as the basis for treatment standards. The total constituent concentration is being used when the technology basis includes a metal recovery operation. The underlying principle of metal recovery is that it reduces the amount of metal in a waste by separating the metal for recovery; total constituent concentration in the treated residual, therefore, is an important measure of performance for this technology. Additionally, EPA also believes that it is important that any remaining metal in a treated residual waste not be in a state that is easily leachable; accordingly, EPA is also using the TCLP extract concentration as a measure of performance. It is important to note that for wastes for which treatment standards are based on a metal recovery process, the facility has to comply with both the total and the TCLP extract constituent concentrations prior to land disposing the waste.

In cases where treatment standards for metals are not based on recovery techniques but rather on stabilization, EPA is using only the TCLP value as a measure of performance. The Agency's rationale is that stabilization is not meant to reduce the concentration of metal in a waste but only to chemically minimize the ability of the metal to leach.

1.2.6 Identification of BDAT

BDAT for a waste must be the "best" of the demonstrated available technologies. EPA determines which technology constitutes "best" after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each demonstrated technology to that of the others. If only one technology is identified as demonstrated, it is considered "best"; if it is available, the technology is BDAT.

(1) Screening of treatment data. The first activity in determining which of the treatment technologies represent treatment by BDAT is to screen the treatment performance data from each of the demonstrated and available technologies according to the following criteria:

1. Design and operating data associated with the treatment data must reflect a well-designed, well-operated system for each treatment data point. (The specific design and operating parameters for each demonstrated technology for the waste code(s) of interest are discussed in Section 3.2 of this document.)

2. Sufficient QA/QC data must be available to determine the true values of the data from the treated waste. This screening criterion involves adjustment of treated data to take into account that the true value may be different from the measured value. This discrepancy generally is caused by other constituents in the waste that can mask results or otherwise interfere with the analysis of the constituent of concern.

3. The measure of performance must be consistent with EPA's approach to evaluating treatment by type of constituents (e.g., total concentration data for organics, and total concentration and TCLP extract concentration for metals from the residual).

In the absence of data needed to perform the screening analysis, EPA will make decisions on a case-by-case basis as to whether to use the data as a basis for the treatment standards. The factors included in this case-by-case analysis will be the actual treatment levels achieved, the availability of the treatment data and their completeness (with respect to the above criteria), and EPA's assessment of whether the untreated waste represents the waste code of concern.

(2) Comparison of treatment data. In cases in which EPA has treatment data from more than one demonstrated available technology following the screening activity, EPA uses the statistical method known as analysis of variance (ANOVA) to determine if one technology performs significantly better than the others. This statistical method (summarized in Appendix A) provides a measure of the differences between two data sets. Specifically, EPA uses the analysis of variance to determine whether BDAT represents a level of performance achieved by only one technology or represents a level of performance achieved by more than one (or all) of the technologies. If EPA finds that one technology performs significantly better (i.e., is "best"), BDAT treatment standards

are the level of performance achieved by that best technology multiplied by the corresponding variability factor for each regulated constituent. If the Agency finds that the levels of performance for one or more technologies are not statistically different, EPA averages the performance values achieved by each technology and then multiplies this value by the largest variability factor associated with any of the technologies.

(3) Quality assurance/quality control. This section presents the principal quality assurance/quality control (QA/QC) procedures employed in screening and adjusting the data to be used in the calculation of treatment standards. Additional QA/QC procedures used in collecting and screening data for the BDAT program are presented in EPA's Generic Quality Assurance Project Plan for Land Disposal Restrictions Program ("BDAT"), EPA/530-SW-87-011.

To calculate the treatment standards for the land disposal restriction rules, it is first necessary to determine the recovery value for each constituent (the amount of constituent recovered after spiking--which is the addition of a known amount of the constituent--minus the initial concentration in the samples, all divided by the spike amount added) for each spiked sample of the treated residual. Once the recovery values are determined, the following procedures are used to select the appropriate percent recovery value to adjust the analytical data:

1. If duplicate spike recovery values are available for the constituent of interest, the data are adjusted by the lowest available percent recovery value (i.e., the value that will yield the most conservative estimate of treatment achieved). However, if a spike recovery value of less than 20 percent is reported for a specific constituent, the data are not used to set treatment standards because the Agency does not have sufficient confidence in the reported value to set a national standard.

2. If data are not available for a specific constituent but are available for an isomer, then the spike recovery data are transferred from the isomer and the data are adjusted using the percent recovery selected according to the procedure described in (1) above.

3. If data are not available for a specific constituent but are available for a similar class of constituents (e.g., volatile organics, acid-extractable semivolatiles), then spike recovery data available for this class of constituents are transferred. All spike recovery values greater than or equal to 20 percent for a spike sample are averaged and the constituent concentration is adjusted by the average recovery value. If spiked recovery data are available for more than one sample, the average is calculated for each sample and the data are adjusted by using the lowest average value.

4. If matrix spike recovery data are not available for a set of data to be used to calculate treatment standards, then matrix spike recovery data are transferred from a waste that the Agency believes is similar (e.g., if the data represent an ash from incineration, then data from other incinerator ashes could be used). While EPA recognizes that transfer of matrix spike recovery data from a similar waste is not an exact analysis, this is considered the best approach for adjusting the data to account for the fact that most analyses do not result in extraction of 100 percent of the constituent. In assessing the recovery data to be transferred, the procedures outlined in (1), (2), and (3) above are followed.

The analytical procedures employed to generate the data used to calculate the treatment standards are listed in Appendix B of this document. In cases where alternatives or equivalent procedures and/or equipment are allowed in EPA's SW-846, Third Edition methods, the specific procedures and equipment used are documented. In addition, any deviations from the SW-846, Third Edition methods used to analyze the specific waste matrices are documented. It is important to note that the Agency will use the methods and procedures delineated in Appendix B to enforce the treatment standards presented in Section 7 of this document. Accordingly, facilities should use these procedures in assessing the performance of their treatment systems.

1.2.7 BDAT Treatment Standards for "Derived-From" and "Mixed" Wastes

(1) Wastes from treatment trains generating multiple residues. In a number of instances, the proposed BDAT consists of a series of operations, each of which generates a waste residue. For example, the proposed BDAT for a certain waste code is based on solvent extraction, steam stripping, and activated carbon adsorption. Each of these treatment steps generates a waste requiring treatment--a solvent-containing stream from solvent extraction, a stripper overhead, and spent activated carbon. Treatment of these wastes may generate further residues; for instance, spent activated carbon (if not regenerated) could be incinerated, generating an ash and possibly a scrubber water waste. Ultimately, additional wastes are generated that may require land disposal. With respect to these wastes, the Agency wishes to emphasize the following points:

1. All of the residues from treating the original listed wastes are likewise considered to be the listed waste by virtue of the derived-from rule contained in 40 CFR 261.3(c)(2). (This point is discussed more fully in (2) below.) Consequently, all of the wastes generated in the course of treatment would be prohibited from land disposal unless they satisfy the treatment standard or meet one of the exceptions to the prohibition.

2. The Agency's proposed treatment standards generally contain a concentration level for wastewaters and a concentration level for nonwastewaters. The treatment standards apply to all of the wastes generated in treating the original prohibited waste. Thus, all derived-from wastes meeting the Agency definition of wastewater (less than 1 percent total organic carbon (TOC) and less than 1 percent total suspended solids) would have to meet the treatment standard for wastewaters. All residuals not meeting this definition would have to meet the treatment standard for nonwastewaters. EPA wishes to make clear that this approach is not meant to allow partial treatment in order to comply with the applicable standard.

3. The Agency has not performed tests, in all cases, on every waste that can result from every part of the treatment train. However, the Agency's treatment standards are based on treatment of the most concentrated form of the waste. Consequently, the Agency believes that the less concentrated wastes generated in the course of treatment will also be able to be treated to meet this value.

(2) Mixtures and other derived-from residues. There is a further question as to the applicability of the BDAT treatment standards to residues generated not from treating the waste (as discussed above), but from other types of management. Examples are contaminated soil or leachate that is derived from managing the waste. In these cases, the mixture is still deemed to be the listed waste, either because of the derived-from rule (40 CFR 261.3(c)(2)(i)) or the mixture rule (40 CFR 261.3(a)(2)(iii) and (iv)) or because the listed waste is contained in the matrix (see, for example, 40 CFR 261.33(d)). The prohibition for the particular listed waste consequently applies to this type of waste.

The Agency believes that the majority of these types of residues can meet the treatment standards for the underlying listed wastes (with the possible exception of contaminated soil and debris for which the Agency is currently investigating whether it is appropriate to establish a separate treatability subcategorization). For the most part, these residues will be less concentrated than the original listed waste. The Agency's treatment standards also make a generous allowance for process variability by assuming that all treatability values used to establish the standard are lognormally distributed. The waste also might be amenable to a relatively nonvariable form of treatment technology such as incineration. Finally, and perhaps most important, the rules contain a treatability variance that allows a petitioner to demonstrate that its waste cannot be treated to the level specified in the rule (40 CFR Part 268.44(a)). This provision provides a safety valve that allows persons with unusual waste matrices to demonstrate the appropriateness of a different standard. The Agency, to date, has not received any petitions under this provision (for example, for residues contaminated with a prohibited solvent waste), indicating, in the Agency's view, that the existing standards are generally achievable.

(3) Residues from managing listed wastes or that contain listed wastes. The Agency has been asked if and when residues from managing hazardous wastes, such as leachate and contaminated ground water, become subject to the land disposal prohibitions. Although the Agency believes this question to be settled by existing rules and interpretative statements, to avoid any possible confusion the Agency will address the question again.

Residues from managing First Third wastes, listed California List wastes, and spent solvent and dioxin wastes are all considered to be subject to the prohibitions for the listed hazardous waste as originally generated. Residues from managing California List wastes likewise are subject to the California List prohibitions when the residues themselves exhibit a characteristic of hazardous waste. This determination stems directly from the derived-from rule in 40 CFR 261.3(c)(2) or, in some cases, from the fact that the waste is mixed with or otherwise contains the listed waste. The underlying principle stated in all of these provisions is that listed wastes remain listed until delisted.

The Agency's historic practice in processing delisting petitions that address mixing residuals has been to consider them to be the listed waste and to require that delisting petitioners address all constituents for which the derived-from waste (or other mixed waste) was listed. The language in 40 CFR 260.22(b) states that mixtures or derived-from residues can be delisted provided a delisting petitioner makes a demonstration identical to that which a delisting petitioner would make for the original listed waste. Consequently, these residues are treated as the original listed waste for delisting purposes. The statute likewise takes this position, indicating that soil and debris that are contaminated with listed spent solvents or dioxin wastes are subject to the prohibition for these wastes even though these wastes are not the originally generated waste, but rather are a residual from management (RCRA section 3004(e)(3)). It is EPA's view that all such residues are covered by the existing prohibitions and treatment standards for the listed hazardous waste that these residues contain or from which they are derived.

1.2.8 Transfer of Treatment Standards

EPA is proposing some treatment standards that are not based on testing of the treatment technology on the specific waste subject to the treatment standard. The Agency has determined that the constituents present in the untested waste can be treated to the same performance levels as those observed in other wastes for which EPA has previously developed treatment data. EPA believes that transferring treatment performance data for use in establishing treatment standards for untested wastes is technically valid in cases where the untested wastes are generated from similar industries or processing steps, or have similar waste characteristics affecting performance and treatment selection. Transfer of treatment standards to similar wastes or wastes from similar processing steps requires little formal analysis. However, in a case where only the industry is similar, EPA more closely examines the waste characteristics prior to deciding whether the untested waste constituents can be treated to levels associated with tested wastes.

EPA undertakes a two-step analysis when determining whether constituents in the untested wastes can be treated to the same level of performance as in the tested waste. First, EPA reviews the available waste characterization data to identify those parameters that are expected to affect treatment selection. EPA has identified some of the most important constituents and other parameters needed to select the treatment technology appropriate for the given waste(s) in Section 3.

Second, when analysis suggests that an untested waste can be treated with the same technology as a waste for which treatment performance data are already available, EPA analyzes a more detailed list of characteristics that the Agency believes will affect the performance of the technology. By examining and comparing these characteristics, the Agency determines whether the untested wastes will achieve the same level of treatment as the tested waste. Where the Agency determines that the untested waste can be treated as well or better than the tested waste, the treatment standards can be transferred.

1.3 Variance from the BDAT Treatment Standard

The Agency recognizes that there may exist unique wastes that cannot be treated to the level specified as the treatment standard. In such a case, a generator or owner/operator may submit a petition to the Administrator requesting a variance from the treatment standard. A particular waste may be significantly different from the wastes on which the treatment standards are based because the subject waste contains a more complex matrix that makes it more difficult to treat. For example, complex mixtures may be formed when a restricted waste is mixed with other waste streams by spills or other forms of inadvertent mixing. As a result, the treatability of the restricted waste may be altered such that it cannot meet the applicable treatment standard.

Variance petitions must demonstrate that the treatment standard established for a given waste cannot be met. This demonstration can be made by showing that attempts to treat the waste by available technologies were not successful or by performing appropriate analyses of the waste, including waste characteristics affecting performance, which demonstrate that the waste cannot be treated to the specified levels. Variances will not be granted based solely on a showing that adequate BDAT treatment capacity is unavailable. (Such demonstrations can be made according to the provisions in Part 268.5 of RCRA for case-by-case extensions of the effective date.) The Agency will consider granting generic petitions provided that representative data are submitted to support a variance for each facility covered by the petition.

Petitioners should submit at least one copy to:

The Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

An additional copy marked "Treatability Variance" should be submitted to:

Chief, Waste Treatment Branch
Office of Solid Waste (WH-565)
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

Petitions containing confidential information should be sent with only the inner envelope marked "Treatability Variance" and "Confidential Business Information" and with the contents marked in accordance with the requirements of 40 CFR Part 2 (41 FR 36902, September 1, 1976, amended by 43 FR 4000).

The petition should contain the following information:

1. The petitioner's name and address.
2. A statement of the petitioner's interest in the proposed action.
3. The name, address, and EPA identification number of the facility generating the waste, and the name and telephone number of the plant contact.
4. The process(es) and feed materials generating the waste and an assessment of whether such process(es) or feed materials may produce a waste that is not covered by the demonstration.
5. A description of the waste sufficient for comparison with the waste considered by the Agency in developing BDAT, and an estimate of the average and maximum monthly and annual quantities of waste covered by the demonstration. (Note: The petitioner should consult the appropriate BDAT background document for determining the characteristics of the wastes considered in developing treatment standards.)
6. If the waste has been treated, a description of the system used for treating the waste, including the process design and operating conditions. The petition should include the reasons the treatment standards are not achievable and/or why the petitioner believes the standards are based on inappropriate technology for treating the waste. (Note: The petitioner should refer to the BDAT background document as guidance for determining the design and operating parameters that the Agency used in developing treatment standards.)
7. A description of the alternative treatment systems examined by the petitioner (if any); a description of the treatment system deemed appropriate by the petitioner for the waste in question; and, as appropriate, the concentrations in the treatment residual or extract of the treatment residual (i.e., using the TCLP, where appropriate, for stabilized metals) that can be achieved by applying such treatment to the waste.
8. A description of those parameters affecting treatment selection and waste characteristics that affect performance, including results of all analyses. (See Section 3 for a discussion of

waste characteristics affecting performance that the Agency has identified for the technology representing BDAT.)

9. The dates of the sampling and testing.
10. A description of the methodologies and equipment used to obtain representative samples.
11. A description of the sample handling and preparation techniques, including techniques used for extraction, containerization, and preservation of the samples.
12. A description of analytical procedures used, including QA/QC methods.

After receiving a petition for a variance, the Administrator may request any additional information or waste samples that may be required to evaluate and process the petition. Additionally, all petitioners must certify that the information provided to the Agency is accurate under 40 CFR 268.4(b).

In determining whether a variance will be granted, the Agency will first look at the design and operation of the treatment system being used. If EPA determines that the technology and operation are consistent with BDAT, the Agency will evaluate the waste to determine if the waste matrix and/or physical parameters are such that the BDAT treatment standards reflect treatment of this waste. Essentially, this latter analysis will concern the parameters affecting treatment selection and waste characteristics affecting performance parameters.

In cases where BDAT is based on more than one technology, the petitioner will need to demonstrate that the treatment standard cannot be met using any of the technologies, or that none of the technologies are appropriate for treatment of the waste. After the Agency has made a determination on the petition, the Agency's findings will be published in the Federal Register, followed by a 30-day period for public comment. After review of the public comments, EPA will publish its final determination in the Federal Register as an amendment to the treatment standards in 40 CFR Part 268, Subpart D.

2. INDUSTRY AFFECTED AND WASTE CHARACTERIZATION

According to 40 CFR 261.32, the following coking industry waste is subject to the land disposal restriction provisions of HSWA:

K087: Decanter tank tar sludge from coking operations.

This section discusses the industry affected by the land disposal restrictions for K087 waste, describes the process that generates the waste, and presents available waste characterization data.

2.1 Industry Affected and Process Description

The coking industry is composed of producers of coke and coke byproducts. The Agency estimates that 36 facilities in the coking industry potentially generate K087 waste. The locations of these facilities are provided in Tables 2-1 and 2-2, by State and by EPA region, respectively. These facilities fall under Standard Industrial Classification (SIC) Code 3312.

Coke and coke byproducts result from the carbonization of coal, a process by which coal is thermally pyrolyzed. Coke serves principally as a fuel and reducing agent in the making of iron and steel. The byproducts--coal tar, light oil, ammonia liquor, and coke oven gas--are further refined into commodity chemicals such as ammonium sulfate, benzene, toluene, xylene, naphthalene, anthracene, creosote, and road tar.

In the carbonization process, coal is charged to coke ovens and heated for 15 to 30 hours at temperatures ranging from 500 to 1,100°C (Austin 1984, Perch 1979). Coking temperatures will vary with the coking time, the rate of underfiring, the coal mixture, the moisture content of

Table 2-1 Number of Coke Plants Listed by State

State	Number of plants
Alabama	5
Illinois	2
Indiana	6
Kentucky	1
Maryland	1
Michigan	3
Missouri	1
New York	2
Ohio	5
Pennsylvania	5
Tennessee	2
Utah	1
Virginia	1
West Virginia	1

Reference: USDOE 1988.

Table 2-2 Number of Coke Plants Listed by EPA Region

EPA region	Number of plants
II	2
III	8
IV	8
V	16
VII	1
VIII	1

Reference: USDOE 1988.

the coal, and the desired properties of the coke and byproducts. Gases evolved from the coke oven--water vapor, tar, light oil, and other compounds--are routed to a collection main and subsequently cooled. The condensates and any entrained particulates are channeled to a decanter tank, where tar products and ammonia liquor are separated according to density. The heavy residue (sludge) that settles to the bottom of the decanter tank is K087 waste. The process is depicted in Figure 2-1.

2.2 Waste Characterization

K087 waste generally contains from 6 to 11 percent water and from 89 to 94 percent coal tar compounds, chiefly aromatic hydrocarbons such as those found in pitch; anthracene oil; and light, middle, and heavy oils. BDAT list semivolatile organics are present at concentrations up to 28 percent; concentrations of BDAT list volatile organics measure approximately 0.1 percent. BDAT list metals and inorganics other than metals are present in quantities less than 0.05 percent. Table 2-3 provides an approximation of the composition of K087 waste, which is based on the available waste characterization data summarized in Table 2-4. Waste characteristics that may affect treatment selection or performance include (1) the high heating value, 13,000 to 15,300 Btu/lb; (2) the ash content, 2.7 to 9.7 percent; and (3) the total organic carbon (TOC) content, 76 to 86 percent.

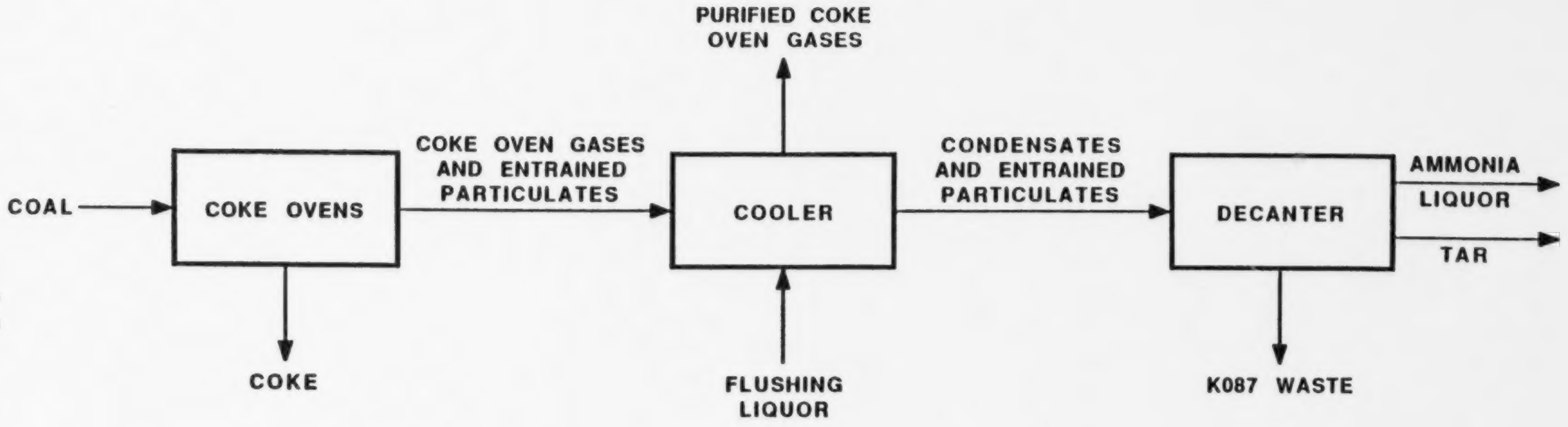

PURIFIED COKE OVEN GASES
COAL
COKE OVENS
COKE OVEN GASES AND ENTRAINED PARTICULATES
COOLER
CONDENSATES AND ENTRAINED PARTICULATES
DECANTER
AMMONIA LIQUOR
TAR
COKE
FLUSHING LIQUOR
K087 WASTE

FIGURE 2-1 SCHEMATIC DIAGRAM OF K087 WASTE GENERATING PROCESS

Table 2-3 Approximate Composition of K087 Waste

Constituent	Concentration (%)
Non-BDAT organics (chiefly coal tar aromatic hydrocarbons)	60-80
BDAT semivolatile organics	15-28
Water	6-11
BDAT volatile organics	<0.1
BDAT metals and inorganics	<0.05

Table 2-4 K087 Waste Composition and Other Data

Constituent/parameter (units)	Concentration (source)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
BDAT Volatile Organics (mg/kg)							
Benzene	6 - 212	173	410	-	400	-	-
Methyl ethyl ketone	<2 - <10	-	-	-	-	-	-
Toluene	17 - 152	97	224	-	260	-	-
Xylenes	3 - 123	79	233	700	260	-	-
BDAT Semivolatile Organics (mg/kg)							
Acenaphthalene	10000 - 13000	24200	24100	20500	21500	-	-
Acenaphthene	<894 - <1026	<1290	564	380	900	-	-
Anthracene	6700 - 8100	14200	8450	10400	10400	-	-
Benz(a)anthracene	5400 - 7500	6790	8465	7800	4600	-	-
Benzenethiol	310	-	-	-	-	-	-
Benzo(b)fluoranthene	<982 - 5300	8650	10345[a]	5400	1900	-	-
Benzo(ghi)perylene	<894 - <1026	2560	3050	6700	1500	-	-
Benzo(k)fluoranthene	<1026 - 9300	-	10345[a]	5500	2900	-	-
Benzo(a)pyrene	3800 - 5400	4640	6030	8450	5500	-	8000
Chrysene	4700 - 6500	6690	4995	7950	4480	-	-
ortho-Cresol	<894 - <1026	<1290	396	<400	425	-	-
para-Cresol	1200 - 1900	<1290	1350	5450	1850	-	-
Dibenzo(ah)anthracene	<894 - <1026	<1290	1000	1750	580	-	-
2,4-Dimethylphenol	<894 - <1026	<1290	256	<400	820	-	-
Fluoranthene	<982 - 1200	28200	24750	25000	13800	-	17000
Fluorene	7000 - 9300	14200	11950	8050	7100	-	-
Indeno(1,2,3-cd)pyrene	2100 - 3100	2370	3145	6150	1600	-	-
Naphthalene	64000 - 81000	49500	40800	95000	51500	-	36000
Phenanthrene	15000 - 41000	43200	34750	36000	19000	-	-
Phenol	1200 - 1800	2380	1970	5900	3150	-	490
Pyrene	5900 - 9700	14800	15800	20500	13500	-	15000
BDAT Metals (mg/kg)							
Antimony	<2.0	-	-	-	-	-	-
Arsenic	1.9 - 6.1	-	-	-	-	-	0.28-20
Barium	<20	-	-	-	-	-	-
Beryllium	<0.5	-	-	-	-	-	-
Cadmium	1.7 - 2.1	-	-	-	-	-	-
Chromium	<2.0	-	-	-	-	-	-
Copper	<2.5 - 4.5	-	-	-	-	-	-
Lead	64 - 85	-	-	-	-	-	31-154
Mercury	2.9 - 4.2	-	-	-	-	-	-
Nickel	<4.0 - 4.6	-	-	-	-	-	-
Selenium	1.2 - 1.6	-	-	-	-	-	-
Silver	<5.0	-	-	-	-	-	-
Thallium	2.1 - 2.7	-	-	-	-	-	-
Vanadium	<5.0	-	-	-	-	-	-
Zinc	50 - 66	-	-	-	-	-	-

Table 2-4 (Continued)

Constituent/parameter (units)	Concentration (source)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
BDAT Inorganics other than Metals (mg/kg)							
Cyanide	17.9 - 228	-	-	-	-	-	-
Fluoride	0.18 - 0.38	-	-	-	-	-	-
Sulfide	275 - 323	-	-	-	-	-	-
Non-BDAT Volatile Organics (mg/kg)							
Styrene	3.4 - 26	-	155	-	-	-	-
Non-BDAT Semivolatile Organics (mg/kg)							
Dibenzofuran	5000 - 6800	-	-	-	-	-	-
1-Methylnaphthalene	-	-	-	4650	4200	-	-
2-Methylnaphthalene	6200 - 9400	7190	6010	8500	10200	-	-
Other Parameters							
Ash content (%)	2.7 - 9.7	-	-	-	-	0.9 - 2.7	3.35
Heating value (Btu/lb)	14800 - 15300	-	-	-	-	13000 - 14400	-
Total halogens as chlorine (%)	0.02 - 0.06	-	-	-	-	-	-
Oil and grease (%)	-	-	-	37	27	22.5	-
Percent water (%)	5.7 - 11.3	-	-	-	-	-	20
Total organic carbon (%)	76.0 - 86.0	-	-	-	-	-	-
Total organic halides (mg/kg)	25.8 - 87.7	-	-	-	-	-	-
Total solids (%)	87 - 91	-	-	-	-	-	-
Viscosity	-[b]	-	-	-	-	-	-

[a] Benzo(b and/or k)fluoranthene.

[b] Because of the high concentration of filterable solids in the waste, viscosity values could not be determined.

- = Not analyzed.

Source references:

(1) USEPA 1988a.

(2) Memorandum, Coke By-Product Sampling Data Summary, from Brenda Shine, Midwest Research Institute, to Edwin F. Abrams, USEPA, September 29, 1987, Coke Plant No. 6, Record Sample.

(3) Ibid., Coke Plant No. 1, Record Sample.

(4) Ibid., Samples CLS Run 1.

(5) Ibid., Samples CU-1.

(6) Environ 1985.

(7) Letters from Earle F. Young, Jr., American Iron and Steel Institute, to Dwight Hlustick, USEPA, December 2, 1986, and to Steve E. Silverman, USEPA, July 25, 1986; letter and attachment from Edward M. Bryan, Petar Energy Corporation, to Valdas Adamkus, USEPA, Region V, March 5, 1982.

3. APPLICABLE/DEMONSTRATED TREATMENT TECHNOLOGIES

This section identifies the applicable and demonstrated treatment technologies for K087 waste. Detailed discussions are provided for the technologies that are demonstrated.

3.1 Applicable Treatment Technologies

As shown in Section 2.2, K087 waste contains BDAT list organic constituents and much lesser concentrations of BDAT list metals. The Agency has identified fuel substitution and incineration as applicable technologies for treating the BDAT list organic constituents in K087 waste. As treatment processes, fuel substitution and incineration have the same purpose: to thermally destroy the organic constituents in the waste by converting them to carbon dioxide, water, and other combustion products. Fuel substitution, in addition to destroying organic constituents, uses the waste as a substitute for conventional fuels burned in high-temperature industrial processes.

Both fuel substitution and incineration result in residuals that may require treatment because of their metal content. Specifically, the residuals consist of ash and scrubber water. Note that residuals generated by fuel substitution technologies that meet certain EPA facility requirements, and for which 50 percent of the fuel is coal, may not be subject to any treatment standards under the Bevill exemption (see 52 FR 17012, May 6, 1987). EPA's determination regarding the application of the Bevill exemption will be addressed in EPA's rulemaking for burning hazardous wastes in boilers and industrial furnaces.

The applicable technology for treatment of metals in the scrubber water is a wastewater treatment system that includes (1) a chemical precipitation step to precipitate metals out of solution, and (2) a settling step or a sludge filtration step to remove the precipitated residues from solution.

For the metals in the ash and in the precipitated residues from chemical precipitation, the only applicable technology that EPA has identified is stabilization. The purpose of stabilization is to immobilize the metal constituents of concern, thereby reducing their leaching potential.

In addition to the specific organic and metal treatment technologies, EPA has also identified recycling as applicable to the K087 waste. Recycling involves treating the K087 waste for (1) reuse in the coke ovens or (2) production of a commercial tar product. Treatment prior to reuse would involve, for example, mixing the waste with coke oven flushing liquor, grinding the material in a ball mill, and mixing the milled material with coal to be fed to the coke ovens for coke production. Alternatively, the waste may be added to hot tar, ground in a ball mill, and packaged as a salable product.

3.2 Demonstrated Technologies

Fuel substitution and incineration, the applicable technologies for BDAT list organics in K087 waste, are "demonstrated" on K087 waste. Data submitted by industry indicate that fuel substitution and incineration are commonly practiced on a full-scale basis. EPA has identified one facility that uses fuel substitution and four facilities that use offsite incineration. Wastes from three of these facilities undergo multiple hearth incineration. While the Agency believes that many other facilities also use fuel substitution and incineration, it has insufficient information to estimate the number of such facilities.

Fuel substitution and incineration are discussed in detail in Sections 3.2.1 and 3.2.2, respectively. Performance data for rotary kiln incineration are presented in Section 4.

The Agency has not identified any facilities using chemical precipitation followed by settling or, alternatively, sludge filtration on the scrubber water generated by rotary kiln incineration of K087 waste. This treatment, however, is demonstrated on a metal-bearing wastewater having similar parameters that affect treatment selection, and thus the Agency considers this treatment to be demonstrated for the K087 scrubber water. Sections 3.2.3 and 3.2.4 describe chemical precipitation, settling, and sludge filtration, as well as the parameters affecting the selection of these treatment technologies. Performance data for chemical precipitation and sludge filtration of the metal-bearing wastewater are presented in Section 4. A comparison of these data to those of the K087 scrubber water shows that the parameters affecting treatment selection are similar.

The Agency has not identified any facilities using stabilization on the treatment sludge that would be generated by treatment of K087 scrubber water or the ash generated by rotary kiln incineration of K087 waste. Stabilization, however, is used on a full-scale basis to treat wastes (e.g., F006 waste) that contain these metals and that have comparable concentrations of filterable solids, total organic carbon, and oil and grease. Thus, the Agency considers stabilization to be demonstrated for both the K087 treatment sludge and the ash. Stabilization is described in Section 3.2.5. Performance data for stabilization of F006 waste are presented in Section 4. These performance data include data on characteristics of the untreated F006 waste.

EPA has identified seven facilities that recycle K087 waste on a full-scale basis. The extent to which recycling is demonstrated is of concern, however, because, unlike the other technologies, recycling may adversely affect coke or tar product quality at some facilities. The Agency has little data available to assist in defining which subcategories of K087 waste can be recycled. Specific data were submitted by the American Iron and Steel Institute (AISI) concerning the practice of recycling K087 wastes (51 FR 17019, May 6, 1987). These data characterize the final coke and coal tar products that result from production which does not involve recycling of K087 waste and production which does involve such recycling. These data indicate that recycling has little, if any, impact on the amount of hazardous constituents in the coke or coal tar, and thus lead the Agency to infer that recycling is not likely to affect product quality. However, the AISI data provided characterization for only one sample of untreated K087 decanter tar sludge. These data, therefore, do not provide sufficient evidence to support the premise that recycling can be accomplished for all K087 wastes.

3.2.1 Fuel Substitution

Fuel substitution involves using hazardous waste as a fuel in industrial furnaces or in boilers for generation of steam. The hazardous waste may be blended with other nonhazardous wastes (e.g., municipal sludge) and/or fossil fuels.

(1) Applicability and use of fuel substitution. Fuel substitution has been used with industrial waste solvents, refinery wastes, synthetic fibers/petrochemical wastes, and waste oils. It can also be used when combusting other waste types produced during the manufacture of pharmaceuticals, pulp and paper, and pesticides. These wastes can be handled in a solid, liquid, or gaseous form.

The most common types of units in which waste fuels are burned are industrial furnaces and industrial boilers. Industrial furnaces include a diverse variety of industrial processes that produce heat and/or products by burning fuels. They include blast furnaces, smelters, and coke ovens. Industrial boilers are units wherein fuel is used to produce steam for process and plant use. Industrial boilers typically use coal, oil, or gas as the primary fuel source.

A number of parameters affect the selection of fuel substitution. These parameters are as follows:

- Halogen content of the waste;
- Inorganic solids content (ash content) of the waste, particularly heavy metals;
- Heating value of the waste;
- Viscosity of the waste (for liquids);
- Filterable solids concentration (for liquids); and
- Sulfur content.

If halogenated organics are burned, halogenated acids and free halogen are among the products of combustion. These released corrosive gases may require subsequent treatment prior to venting to the atmosphere. Also, halogens and halogenated acids formed during combustion are likely to severely corrode boiler tubes and other process equipment. For this reason, halogenated wastes are blended into fuels only at very low concentrations to minimize such problems. High chlorine content can also lead to the incidental production (at very low concentrations) of other hazardous compounds such as polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and chlorinated phenols.

High inorganic solids content (i.e., ash content) of wastes may cause two problems: (1) scaling in the boiler and (2) particulate air emissions. Scaling results from deposition of inorganic solids on the walls of the boiler. Particulate emissions are produced by noncombustible inorganic constituents that flow out of the boiler with the gaseous combustion products. Because of these problems, wastes with significant concentrations of inorganic materials are not usually handled in boilers unless the boilers have an air pollution control system.

Industrial furnaces vary in their tolerance to inorganic constituents. Heavy metal concentrations, found in both halogenated and nonhalogenated wastes used as fuel, can cause environmental concern because they may be emitted in the gaseous emissions from the combustion process, in the ash residues, or in any produced solids. The partitioning of the heavy metals to these residual streams primarily depends on the volatility of the metal, waste matrix, and furnace design.

The heating value of the waste must be sufficiently high (either alone or in combination with other fuels) to maintain combustion temperatures consistent with efficient waste destruction and operation of the boiler or furnace. For many applications, only supplemental fuels having minimum heating values of 4,400 to 5,600 kcal/kg (8,000 to 10,000 Btu/lb) are considered to be feasible. Below this value, the unblended fuel would not be likely to maintain a stable flame, and its combustion would release insufficient energy to provide needed steam generation potential in the boiler or the necessary heat for an industrial furnace. Some wastes with heating values of less than 4,400 kcal/kg (8,000 Btu/lb) can be used if sufficient auxiliary fuel is employed to support combustion or if special designs are incorporated into the combustion device. Occasionally, for wastes with heating values higher than virgin fuels, blending with auxiliary fuel may be required to prevent overheating or overcharging the combustion device.

In combustion devices designed to burn liquid fuels, the viscosity of liquid waste must be low enough that the liquid can be atomized in the combustion chamber. If the viscosity is too high, heating of storage tanks may be required prior to combustion. For atomization of liquids, a viscosity of 165 centistokes (750 Saybolt Seconds Universal (SSU)) or less is typically required.

Filterable material suspended in the liquid fuel may prevent or hinder pumping or atomization.

Sulfur content in the waste may prevent burning of the waste because of potential atmospheric emissions of sulfur oxides. For instance, there are proposed Federal sulfur oxide emission regulations for certain new source industrial boilers (51 FR 22385). Air pollution control devices are available to remove sulfur oxides from the stack gases.

(2) Underlying principles of operation. For a boiler and most industrial furnaces, there are two distinct principles of operation. Initially, energy in the form of heat is transferred to the waste to achieve volatilization of the various waste constituents. For liquids, volatilization energy may also be supplied by using pressurized atomization. The energy used to pressurize the liquid waste allows the atomized waste to break into smaller particles, thus enhancing its rate of volatilization. The volatilized constituents then require additional energy to destabilize the chemical bonds and allow the constituents to react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the chemical bonds is referred to as the energy of activation.

(3) Description of the fuel substitution process. As stated, a number of industrial applications can use fuel substitution. Therefore, there is no one process description that will fit all of these applications. However, the following section provides a general description of industrial kilns (one form of industrial furnace) and industrial boilers.

(a) Kilns. Combustible wastes have the potential to be used as fuel in kilns and, for waste liquids, are often used with oil to co-fire kilns. Coal-fired kilns are capable of handling some solid wastes. In the case of cement kilns, there are usually no residuals requiring land disposal since any ash formed becomes part of the product or is removed by particulate collection systems and recycled back to the kiln. The only residuals may be low levels of unburned gases escaping with combustion products. If this is the case, air pollution control devices may be required.

Three types of kilns are particularly applicable: cement kilns, lime kilns, and lightweight aggregate kilns.

(i) Cement kilns. The cement kiln is a rotary furnace, which is a refractory-lined steel shell used to calcine a mixture of calcium, silicon, aluminum, iron, and magnesium-containing minerals. The kiln is normally fired by coal or oil. Liquid and solid combustible wastes may then serve as auxiliary fuel. Temperatures within the kiln are typically between 1,380 and 1,540°C (2,500 to 2,800°F). To date, only liquid hazardous wastes have been burned in cement kilns.

Most cement kilns have a dry particulate collection device (i.e., either an electrostatic precipitator or baghouse), with the collected fly ash recycled back to the kiln. Buildup of metals or other noncombustibles is prevented through their incorporation in the product cement. Since many types of cement require a source of chloride, most halogenated liquid hazardous wastes currently can be burned in cement kilns. Available information shows that scrubbers are not used.

(ii) Lime kilns. Quick-lime (CaO) is manufactured in a calcination process using limestone ($CaCO_3$) or dolomite ($CaCO_3$ and $MgCO_3$). These raw materials are also heated in a refractory-lined rotary kiln, typically to temperatures of 980 to 1,260°C (1,800 to 2,300°F). Lime kilns are less likely to burn hazardous wastes than are cement kilns because product lime is often added to potable water systems. Only one lime kiln currently burns hazardous waste in the U.S. That particular facility sells its product lime for use as flux or as refractory in blast furnaces.

As with cement kilns, any collected fly ash is recycled back to the lime kiln, resulting in no residual streams from the kiln. Available information shows that scrubbers are not used.

(iii) Lightweight aggregate kilns. Lightweight aggregate kilns heat clay to produce an expanded lightweight inorganic material used in portland cement formulations and other applications. The kiln has a normal temperature range of 1,100 to 1,150°C (2,000 to 2,100°F). Lightweight aggregate kilns are less amenable to combustion of hazardous wastes as fuels than the other kilns described above because of the lack of material in the kiln to adsorb halogens. As a result, burning of halogenated organics in these kilns would likely require afterburners to ensure complete destruction of the halogenated organics and scrubbers to control acid gas production. Such controls would produce a wastewater residual stream subject to treatment standards.

(b) Industrial boilers. A boiler is a closed vessel in which water is transformed into steam by the application of heat. Normally, heat is supplied by the combustion of pulverized coal, fuel oil, or gas. These fuels are fired into a combustion chamber with nozzles and burners that provide mixing with air. Liquid wastes, and granulated solid wastes in the case of grate-fired boilers, can be burned as auxiliary fuel in a boiler. Few grate-fired boilers burn hazardous wastes, however. For liquid-fired boilers, residuals requiring land disposal are generated only when the boiler is shut down and cleaned. This is generally done once or twice per year. Other residuals from liquid-fired boilers would be the gas emission stream, which would consist of any products of incomplete combustion, along with the normal combustion products. For example, chlorinated wastes would produce acid gases. If this is the case, air pollution control devices may be required. For solid-fired boilers, an ash normally is generated. This ash may contain residual amounts of organics from the blended waste/fuels, as well as noncombustible materials. Land disposal of this ash would require compliance with applicable BDAT treatment standards.

(4) Waste characteristics affecting performance. For cement kilns and lime kilns and for lightweight aggregate kilns burning nonhalogenated wastes (i.e., no scrubber is needed to control acid gases), no residual waste streams would be produced. Any noncombustible material in the waste would leave the kiln in the product stream. As a result, in transferring standards EPA would not examine waste characteristics affecting performance but rather would determine the applicability of fuel substitution. That is, EPA would investigate the parameters affecting treatment selection. As mentioned previously, for kilns these parameters are Btu content, percent filterable solids, halogenated organics content, viscosity, and sulfur content.

Lightweight aggregate kilns burning halogenated organics and boilers burning wastes containing any noncombustibles will produce residual streams subject to treatment standards. In determining whether fuel substitution is likely to achieve the same level of performance on an untreated waste as on a previously treated waste, EPA will examine: (1) relative volatility of the waste constituents, (2) the heat transfer characteristics (for solids), and (3) the activation energy for combustion.

(a) Relative volatility. The term relative volatility (α) refers to the ease with which a substance present in a solid or liquid waste will vaporize from that waste upon application of heat from an external source. Hence, it bears a relationship to the equilibrium vapor pressure of the substance.

EPA recognizes that the relative volatilities cannot be measured or calculated directly for the types of wastes generally treated in an industrial boiler or furnace. The Agency believes that the best measure of relative volatility is the boiling point of the various hazardous constituents, and will, therefore, use this parameter in assessing volatility of the organic constituents.

(b) Heat transfer characteristics. Consistent with the underlying principles of combustion in aggregate kilns or boilers, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of industrial boilers burning solid fuels, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given boiler it can be assumed that the type of waste will have a minimal impact on the heat transferred from radiation. With regard to convection, EPA believes that the range of wastes treated would exhibit similar properties with regard to the amount of heat transferred by convection. Therefore, EPA will not evaluate radiation convection heat transfer properties of wastes in determining similar treatability. For solids, the third heat transfer mechanism, conductivity, is the one principally operative or most likely to vary between wastes.

Using thermal conductivity measurements as part of a treatability comparison for two different wastes through a given boiler or furnace is most meaningful when applied to wastes that are homogeneous. As wastes exhibit greater degrees of nonhomogeneity, thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance and not heat flow through all parts of the waste). Nevertheless, EPA has not identified a better alternative to thermal conductivity, even for wastes that are nonhomogeneous.

Other parameters considered for predicting heat transfer characteristics were Btu value, specific heat, and ash content. These parameters can neither better account for nonhomogeneity nor better predict heat transferability through the waste.

(c) *Activation energy.* Given an excess of oxygen, an organic waste in an industrial furnace or boiler would be expected to convert to carbon dioxide and water provided that the activation energy is achieved. Activation energy is the quantity of heat (energy) needed to destabilize molecular bonds and create reactive intermediates so that the oxidation (combustion) reaction will proceed to completion. As a measure of activation energy, EPA is using bond dissociation energies. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case.

In some instances, bond energies will not be available and will have to be estimated, or other energy effects (e.g., vibrational) and other reactions will have a significant influence on activation energy. Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested to a tested waste. These parameters included heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state (i.e., the energy input needed to initiate the reaction). Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of available kinetic data was rejected because while such data could be used to calculate some free energy values (ΔG), they could not be used for the wide range of hazardous constituents. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct comparison.

(5) Design and operating parameters.

(a) Design parameters. Cement kilns and lime kilns, along with aggregate kilns burning nonhalogenated wastes, produce no residual streams. Their design and operation is such that any wastes that are incompletely destroyed will be contained in the product. As a result, the Agency will not look at design and operating values for such devices since treatment, per se, cannot be measured through detection of constituents in residual streams. In this instance, it is important merely to ensure that the waste is appropriate for combustion in the kiln and that the kiln is operated in a manner that will produce a usable product.

Specifically, cement, lime, and aggregate kilns are demonstrated only on liquid hazardous wastes. Such wastes must be sufficiently free of filterable solids to avoid plugging the burners at the hot end of the kiln. Viscosity also must be low enough for the waste to be injected into the kiln through the burners. The sulfur content is not a concern unless the concentration in the waste is sufficiently high as to exceed Federal, State, or local air pollution standards promulgated for industrial boilers.

The design parameters that normally affect the operation of an industrial boiler (and aggregate kilns with residual streams) with respect to hazardous waste treatment are (1) the design temperature, (2) the design retention time of the waste in the combustion chamber, and (3) turbulence in the combustion chamber. Evaluation of these parameters would be important in determining whether an industrial boiler or industrial furnace is adequately designed for effective treatment of hazardous wastes. The rationale for selection of these three parameters is given below.

(i) Design temperature. Industrial boilers are generally designed based on their steam generation potential (Btu output). This factor is related to the design combustion temperature, which in turn depends on the amount of fuel burned and its Btu value. The fuel feed rates and combustion temperatures of industrial boilers are generally fixed based on the Btu values of fuels normally handled (e.g., No. 2 versus No. 6 fuel oils). When wastes are to be blended with fossil fuels for combustion, the blending, based on Btu values, must be such that the resulting Btu value of the mixture is close to that of the fuel value used in design of the boiler. Industrial furnaces also are designed to operate at specific ranges of temperature in order to produce the desired product (e.g., lightweight aggregate). The blended waste/fuel mixture should be capable of maintaining the design temperature range.

(ii) Design retention time. A sufficient retention time of combustion products is normally necessary to ensure that the hazardous substances being combusted (or formed during combustion) are completely oxidized. Retention times on the order of a few seconds are generally needed at normal operating conditions. For industrial furnaces as well as boilers, the retention time is a function of the size of the furnace and the fuel feed rates. For most boilers and furnaces, the retention time usually exceeds a few seconds.

(iii) Turbulence. Boilers are designed so that fuel and air are intimately mixed. This helps ensure that complete combustion takes place. The shape of the boiler and the method of fuel and air feed influence the turbulence required for good mixing. Industrial furnaces also are designed for turbulent mixing where fuel and air are mixed.

(b) Operating parameters. The operating parameters that normally affect the performance of an industrial boiler and many industrial furnaces with respect to treatment of hazardous wastes are

(1) air feed rate, (2) fuel feed rate, (3) steam pressure or rate of production, and (4) temperature. EPA believes that these four parameters will be used to determine whether an industrial boiler burning blended fuels containing hazardous waste constituents is properly operated. The rationale for selection of these four operating parameters is given below. Most industrial furnaces will monitor similar parameters, but some exceptions are noted.

(i) Air feed rate. An important operating parameter in boilers and many industrial furnaces is the oxygen content in the flue gas, which is a function of the air feed rate. Stable combustion of a fuel generally occurs within a specific range of air-to-fuel ratios. An oxygen analyzer in the combustion gases can be used to control the feed ratio of air to fuel to ensure complete thermal destruction of the waste and efficient operation of the boiler. When necessary, the air feed rate can be increased or decreased to maintain proper fuel-to-oxygen ratios. Some industrial furnaces do not completely combust fuels (e.g., coke ovens and blast furnaces); therefore, oxygen concentration in the flue gas is a meaningless variable.

(ii) Fuel feed rate. The rate at which fuel is injected into the boiler or industrial furnace will determine the thermal output of the system per unit of time (Btu/hr). If steam is produced, steam pressure monitoring will indirectly determine whether the fuel feed rate is adequate. However, various velocity and mass measurement devices can be used to monitor fuel flow directly.

(iii) Steam pressure or rate of production. Steam pressure in boilers provides a direct measure of the thermal output of the system and is directly monitored by use of in-system pressure gauges. Increases or decreases in steam pressure can be effected by increasing or decreasing the fuel and air feed rates within certain operating design limits. Most industrial furnaces do not produce steam, but instead produce a product (e.g., cement, aggregate) and monitor the rate of production.

(iv) Temperature. Temperatures are monitored and controlled in industrial boilers to ensure the quality and flow rate of steam. Therefore, complex monitoring systems are frequently installed in the combustion unit to provide a direct reading of temperature. The efficiency of combustion in industrial boilers is dependent on combustion temperatures. Temperature may be adjusted to design settings by increasing or decreasing the air and fuel feed rates.

Wastes should not be added to primary fuels until the boiler temperature reaches the minimum needed for destruction of the wastes. Temperature instrumentation and control should be designed to stop waste addition in the event of process upsets.

Monitoring and control of temperature in industrial furnaces are also critical to the product quality. For example, lime, cement, or aggregate kilns require minimum operating temperatures. Kilns have very high thermal inertia in the refractory and in-process product, high residence times, and high air feed rates, so that even in the case of a momentary stoppage of fuel flow to the kiln, organic constituents are likely to continue to be destroyed. The main operational control required for wastes burned in kilns is to stop waste flow in the event of low kiln temperature, loss of electrical power to the combustion air fan, and loss of primary fuel flow.

(v) Other operating parameters. In addition to the four operating parameters discussed above, EPA considered and then discarded one additional parameter--fuel-to-waste blending ratios. While the blending is done to yield a uniform Btu content fuel, blending ratios will vary widely depending on the Btu content of the wastes and the fuels being used.

3.2.2 Incineration

This section addresses the commonly used incineration technologies: liquid injection, rotary kiln, fluidized bed, and fixed hearth. A discussion is provided regarding the applicability of these technologies, the underlying principles of operation, a technology description, waste characteristics that affect performance, and, finally, important design and operating parameters. As appropriate, the subsections are divided by type of incineration unit.

(1) Applicability and use of incineration.

(a) Liquid injection. Liquid injection is applicable to wastes that have viscosity values low enough that the waste can be atomized in the combustion chamber. A range of literature maximum viscosity values are reported, with the low being 100 SSU and the high being 10,000 SSU. It is important to note that viscosity is temperature dependent so that while liquid injection may not be applicable to a waste at ambient conditions, it may be applicable when the waste is heated. Other factors that affect the use of liquid injection are particle size and the presence of suspended solids. Both of these waste parameters can cause plugging of the burner nozzle.

(b) Rotary kiln/fluidized bed/fixed hearth. These incineration technologies are applicable to a wide range of hazardous wastes. They can be used on wastes that contain high or low total organic content, high or low filterable solids, various viscosity ranges, and a range of other waste parameters. EPA has not found these technologies to be demonstrated on wastes that are composed essentially of metals with low organic concentrations. In addition, the Agency expects that air emissions from incinerating some of the high metal content wastes may not be compatible with existing and future air emission limits without emission controls far more extensive than those currently used.

(2) Underlying principles of operation.

(a) Liquid injection. The basic operating principle of this incineration technology is that incoming liquid wastes are volatilized and then additional heat is supplied to the waste to destabilize the chemical bonds. Once the chemical bonds are broken, these constituents react with oxygen to form carbon dioxide and water vapor. The energy needed to destabilize the bonds is referred to as the energy of activation.

(b) Rotary kiln and fixed hearth. There are two distinct principles of operation for these incineration technologies, one for each of the chambers involved. In the primary chamber, energy, in the form of heat, is transferred to the waste to achieve volatilization of the various organic waste constituents. During this volatilization process some of the organic constituents will oxidize to carbon dioxide and water vapor. In the secondary chamber, additional heat is supplied to overcome the energy requirements needed to destabilize the chemical bonds and allow the constituents to react with excess oxygen to form carbon dioxide and water vapor. The principle of operation for the secondary chamber is similar to that of liquid injection.

(c) Fluidized bed. The principle of operation for this incineration technology is somewhat different from that for rotary kiln and fixed hearth incineration relative to the functions of the primary and secondary chambers. In fluidized bed incineration, the purpose of the primary chamber is not only to volatilize the wastes but also to essentially combust the waste. Destruction of the waste organics can be accomplished to a better degree in the primary chamber of a fluidized bed incinerator than in that of a rotary kiln or fixed hearth incinerator because of (1) improved heat transfer from fluidization of the waste using forced air and (2) the fact that the fluidization process provides sufficient oxygen and turbulence to convert the organics to carbon dioxide and water vapor. The secondary chamber (referred to as the freeboard) generally does not have an afterburner; however, additional time is provided for conversion of the organic constituents to carbon dioxide, water vapor, and hydrochloric acid if chlorine is present in the waste.

(3) Description of the incineration process.

(a) Liquid injection. The liquid injection system is capable of incinerating a wide range of gases and liquids. The combustion system has a simple design with virtually no moving parts. A burner or nozzle atomizes the liquid waste and injects it into the combustion chamber, where it burns in the presence of air or oxygen. A forced draft system supplies the combustion chamber with air to provide oxygen for combustion and turbulence for mixing. The combustion chamber is usually a cylinder lined with refractory (i.e., heat-resistant) brick and can be fired horizontally, vertically upward, or vertically downward. Figure 3-1 illustrates a liquid injection incineration system.

(b) Rotary kiln. A rotary kiln is a slowly rotating, refractory-lined cylinder that is mounted at a slight incline from the horizontal (see Figure 3-2). Solid wastes enter at the high end of the kiln, and liquid or gaseous wastes enter through atomizing nozzles in the kiln or afterburner section. Rotation of the kiln exposes the solids to the heat, vaporizes them, and allows them to combust by mixing with air. The rotation also causes the ash to move to the lower end of the kiln, where it can be removed. Rotary kiln systems usually have a secondary combustion chamber or afterburner following the kiln for further combustion of the volatilized components of solid wastes.

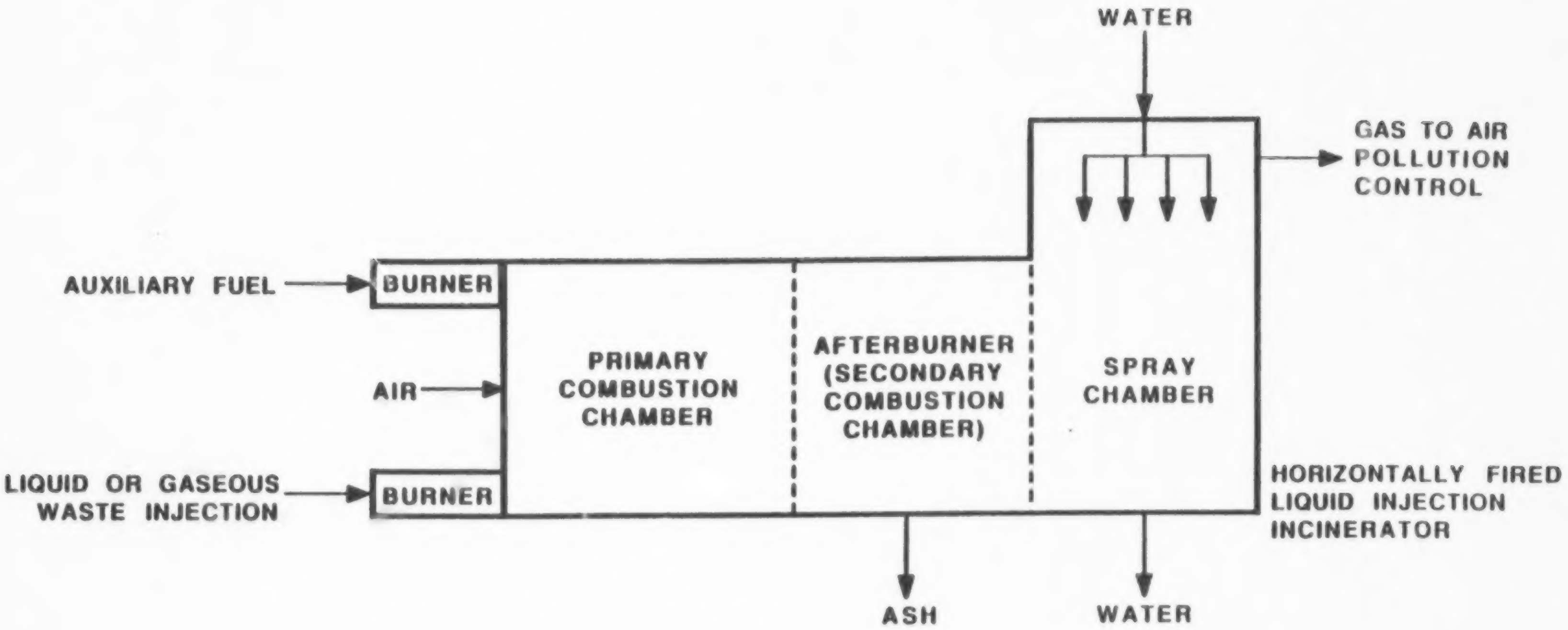

WATER
GAS TO AIR POLLUTION CONTROL
AUXILIARY FUEL
BURNER
AIR
LIQUID OR GASEOUS WASTE INJECTION
BURNER
PRIMARY COMBUSTION CHAMBER
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
SPRAY CHAMBER
HORIZONTALLY FIRED LIQUID INJECTION INCINERATOR
ASH
WATER

FIGURE 3-1
LIQUID INJECTION INCINERATOR

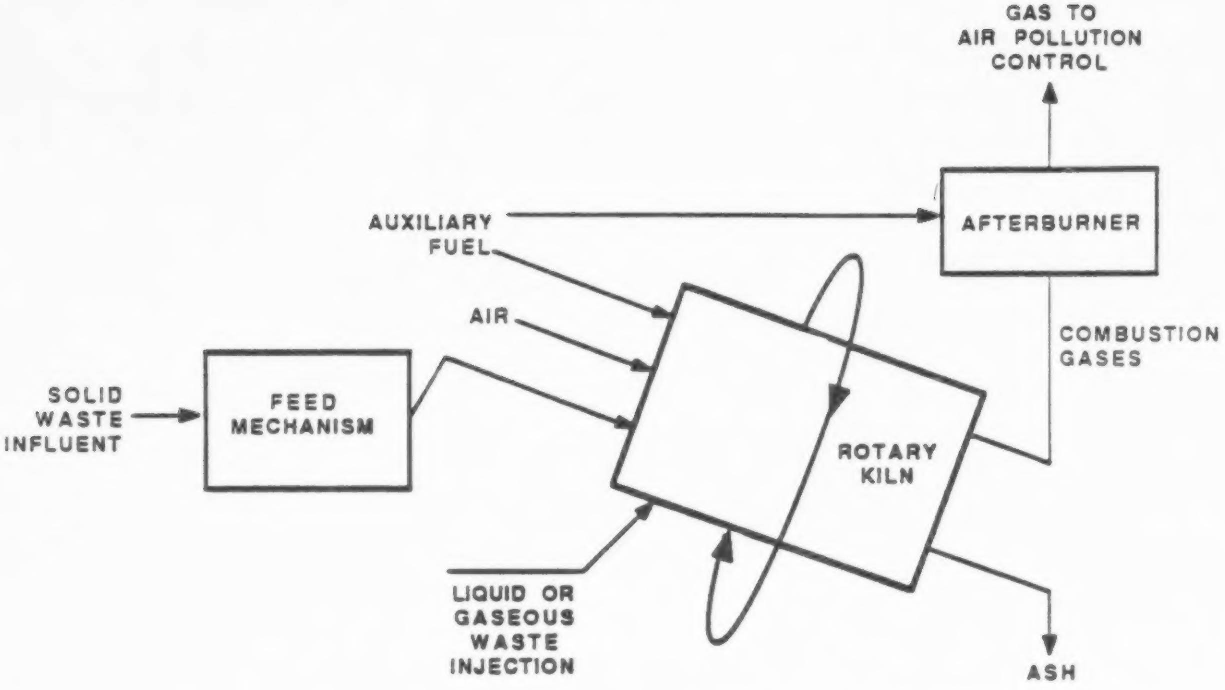

GAS TO
AIR POLLUTION
CONTROL
AUXILIARY
FUEL
AFTERBURNER
AIR
COMBUSTION
GASES
SOLID
WASTE
INFLUENT
FEED
MECHANISM
ROTARY
KILN
LIQUID OR
GASEOUS
WASTE
INJECTION
ASH

FIGURE 3-2
ROTARY KILN INCINERATOR

(c) Fluidized bed. A fluidized bed incinerator consists of a column containing inert particles such as sand, which is referred to as the bed. Air, driven by a blower, enters the bottom of the bed to fluidize the sand. Air passage through the bed promotes rapid and uniform mixing of the injected waste material within the fluidized bed. The fluidized bed has an extremely high heat capacity (approximately three times that of flue gas at the same temperature), thereby providing a large heat reservoir. The injected waste reaches ignition temperature quickly and transfers the heat of combustion back to the bed. Continued bed agitation by the fluidizing air allows larger particles to remain suspended in the combustion zone (see Figure 3-3).

(d) Fixed hearth. Fixed hearth incineration, also called controlled air or starved air incineration, is another major technology used for hazardous waste incineration. Fixed hearth incineration is a two-stage combustion process (see Figure 3-4). Waste is ram-fed into the first stage, or primary chamber, and burned at less than stoichiometric conditions. The resultant smoke and pyrolysis products, consisting primarily of volatile hydrocarbons and carbon monoxide, along with the normal products of combustion, pass to the secondary chamber. Here, additional air is injected to complete the combustion. This two-stage process generally yields low stack particulate and carbon monoxide (CO) emissions. The primary chamber combustion reactions and combustion gas are maintained at low levels by the starved air conditions so that particulate entrainment and carryover are minimized.

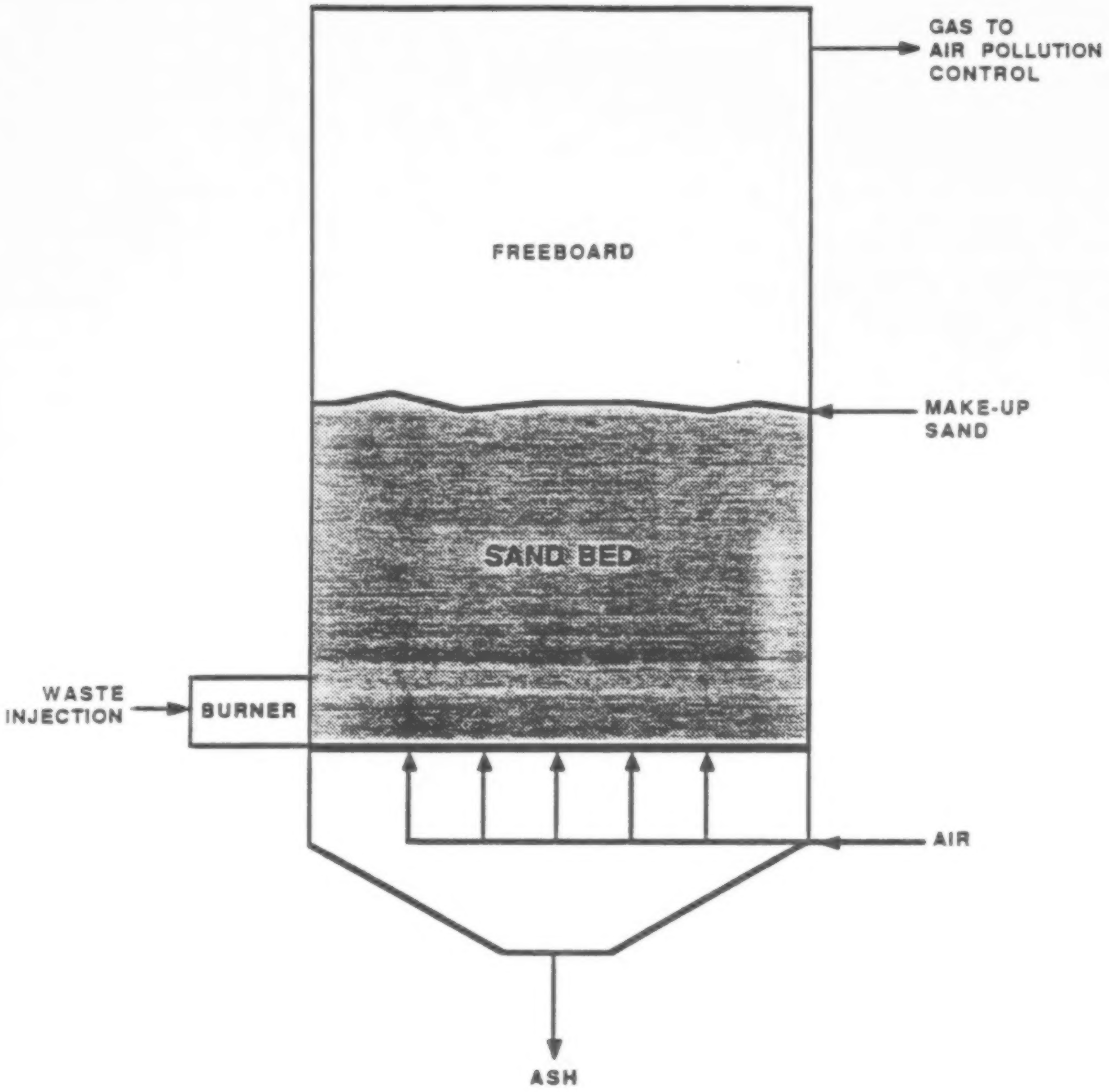

GAS TO
AIR POLLUTION
CONTROL
FREEBOARD
MAKE-UP
SAND
SAND BED
WASTE
INJECTION
BURNER
AIR
ASH

FIGURE 3-3
FLUIDIZED BED INCINERATOR

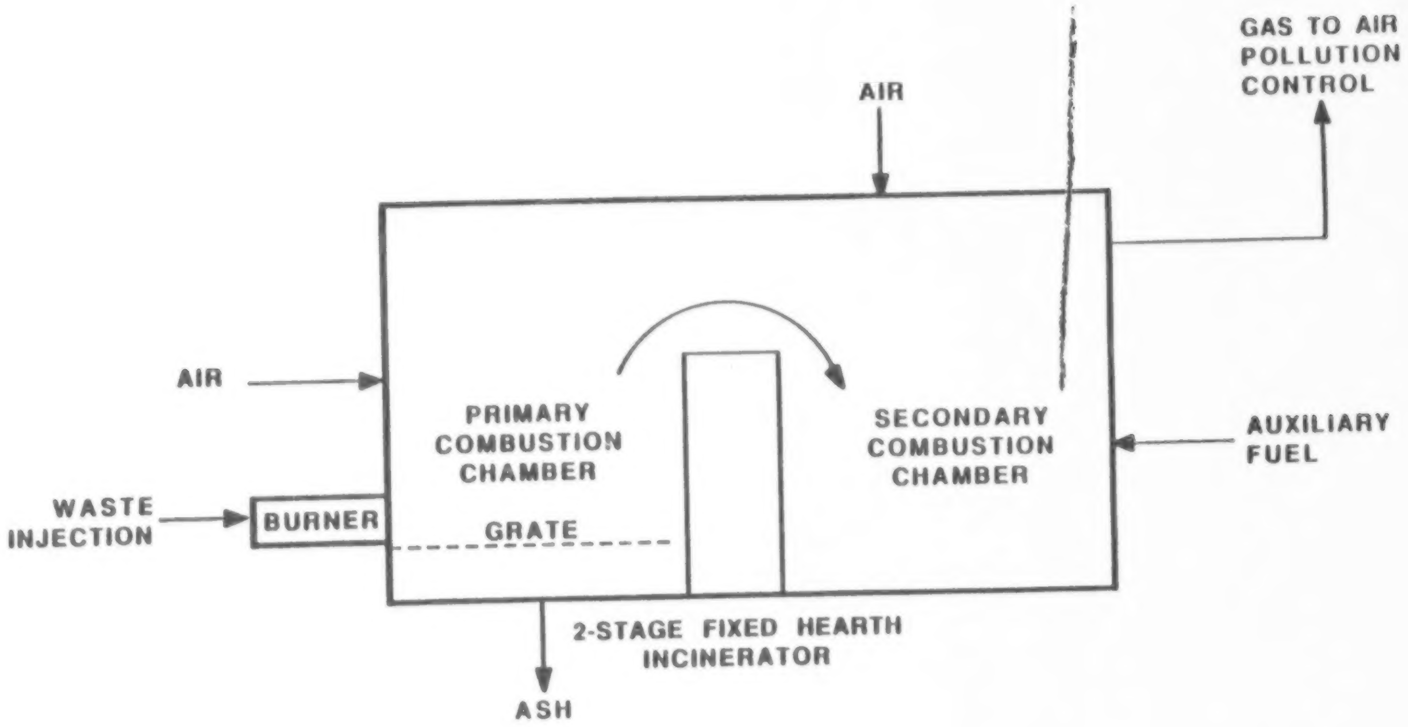

GAS TO AIR POLLUTION CONTROL
AIR
AIR
PRIMARY COMBUSTION CHAMBER
SECONDARY COMBUSTION CHAMBER
AUXILIARY FUEL
WASTE INJECTION
BURNER
GRATE
2-STAGE FIXED HEARTH INCINERATOR
ASH

FIGURE 3-4
FIXED HEARTH INCINERATOR

(e) Air pollution controls. Following incineration of hazardous wastes, combustion gases are generally further treated in an air pollution control system. The presence of chlorine or other halogens in the waste requires a scrubbing or absorption step to remove hydrochloric acid and other halo-acids from the combustion gases. Ash in the waste is not destroyed in the combustion process. Depending on its composition, ash will exit either as bottom ash, at the discharge end of a kiln or hearth for example, or as particulate matter (fly ash) suspended in the combustion gas stream. Particulate emissions from most hazardous waste combustion systems generally have particle diameters of less than 1 micron and require high-efficiency collection devices to minimize air emissions. In addition, scrubber systems provide an additional buffer against accidental releases of incompletely destroyed waste products, which result from poor combustion efficiency or combustion upsets, such as flameouts.

(4) Waste characteristics affecting performance.

(a) Liquid injection. In determining whether liquid injection is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will compare dissociation bond energies of the constituents in the untested and tested wastes. This parameter is being used as a surrogate indicator of activation energy which, as discussed previously, destabilizes molecular bonds. In theory, the bond dissociation energy would be equal to the activation energy; in practice, however, this is not always the case. Other energy effects (e.g., vibrational effects, the formation of intermediates, and interactions between different molecular bonds) may have a significant influence on activation energy.

Because of the shortcomings of bond energies in estimating activation energy, EPA analyzed other waste characteristic parameters to determine whether these parameters would provide a better basis for transferring treatment standards from an untested waste to a tested waste. These parameters include heat of combustion, heat of formation, use of available kinetic data to predict activation energies, and general structural class. All of these parameters were rejected for the reasons provided below.

The heat of combustion measures only the difference in energy of the products and reactants; it does not provide information on the transition state. Heat of formation is used as a tool to predict whether reactions are likely to proceed; however, there are a significant number of hazardous constituents for which these data are not available. Use of kinetic data was rejected because these data are limited and could not be used to calculate free energy values (ΔG) for the wide range of hazardous constituents to be addressed by this rule. Finally, EPA decided not to use structural classes because the Agency believes that evaluation of bond dissociation energies allows for a more direct determination of whether a constituent will be destabilized.

(b) Rotary kiln/fluidized bed/fixed hearth. Unlike liquid injection, these incineration technologies also generate a residual ash. Accordingly, in determining whether these technologies are likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA would need to examine the waste characteristics that affect volatilization of organics from the waste, as well as destruction of the organics once volatilized. Relative to volatilization, EPA will examine thermal conductivity of the entire waste and boiling point of the various constituents. As with liquid injection, EPA will examine bond energies in determining whether treatment standards for scrubber water residuals can be transferred from a tested waste to an untested waste. Below is a discussion of how EPA arrived at thermal conductivity and boiling point as the best method to assess volatilization of organics from the waste; the discussion relative to bond energies is the same for these technologies as for liquid injection and will not be repeated here.

(i) Thermal conductivity. Consistent with the underlying principles of incineration, a major factor with regard to whether a particular constituent will volatilize is the transfer of heat through the waste. In the case of rotary kiln, fluidized bed, and fixed hearth incineration, heat is transferred through the waste by three mechanisms: radiation, convection, and conduction. For a given incinerator, heat transferred through various wastes by radiation is more a function of the design and type of incinerator than of the waste being treated. Accordingly, the type of waste treated will have a minimal impact on the amount of heat transferred by radiation. With regard to convection, EPA also believes that the type of heat transfer will generally be more a function of the type and design of the incinerator than of the waste itself. However, EPA is examining particle size as a waste characteristic that may significantly impact the amount of heat transferred to a waste by convection and thus impact volatilization of the various organic compounds. The final type of heat transfer, conduction, is the one that EPA believes will have the greatest impact on volatilization of organic constituents. To measure this characteristic, EPA will use thermal conductivity; an explanation of this parameter, as well as how it can be measured, is provided below.

Heat flow by conduction is proportional to the temperature gradient across the material. The proportionality constant is a property of the material and is referred to as the thermal conductivity. (Note: The analytical method that EPA has identified for measurement of thermal conductivity is named "Guarded, Comparative, Longitudinal Heat Flow Technique"; it is described in Appendix E.) In theory, thermal conductivity would always provide a good indication of whether a constituent in an untested waste would be treated to the same extent in the primary incinerator chamber as the same constituent in a previously tested waste.

In practice, thermal conductivity has some limitations in assessing the transferability of treatment standards; however, EPA has not identified a parameter that can provide a better indication of the heat transfer characteristics of a waste. Below is a discussion of both the limitations associated with thermal conductivity and the other parameters considered.

Thermal conductivity measurements, as part of a treatability comparison for two different wastes through a single incinerator, are most meaningful when applied to wastes that are homogeneous (i.e., major constituents are essentially the same). As wastes exhibit greater degrees of nonhomogeneity (e.g., significant concentration of metals in soil), then thermal conductivity becomes less accurate in predicting treatability because the measurement essentially reflects heat flow through regions having the greatest conductivity (i.e., the path of least resistance) and not heat flow through all parts of the waste.

Btu value, specific heat, and ash content were also considered for predicting heat transfer characteristics. These parameters can no better account for nonhomogeneity than can thermal conductivity; additionally, they are not directly related to heat transfer characteristics. Therefore, these parameters do not provide a better indication of the heat transfer that will occur in any specific waste.

(ii) Boiling point. Once heat is transferred to a constituent within a waste, removal of this constituent from the waste will depend on its volatility. EPA is using boiling point as a surrogate of volatility of the constituent. Compounds with lower boiling points have higher vapor pressures and therefore would be more likely to vaporize. The Agency recognizes that this parameter does not take into consideration the impact of other compounds in the waste on the boiling point of a constituent in a mixture; however, the Agency is not aware of a better measure of volatility that can easily be determined.

(5) Design and operating parameters.

(a) Liquid injection. For a liquid injection unit, EPA's analysis of whether the unit is well designed will focus on (1) the likelihood that sufficient energy is provided to the waste to overcome the activation level for breaking molecular bonds and (2) whether sufficient oxygen is present to convert the waste constituents to carbon dioxide and water vapor. The specific design parameters that the Agency will evaluate to assess whether these conditions are met are temperature, excess oxygen, and residence time. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

It is important to point out that, relative to the development of land disposal restriction standards, EPA is concerned with these design parameters only when a quench water or scrubber water residual is generated from treatment of a particular waste. If treatment of a particular waste in a liquid injection unit would not generate a wastewater stream, then the Agency, for purposes of land disposal treatment standards, would be concerned only with the waste characteristics that affect selection of the unit, not with the above-mentioned design parameters.

(i) Temperature. Temperature is important in that it provides an indirect measure of the energy available (i.e., Btu/hr) to overcome the activation energy of waste constituents. As the design temperature increases, it is more likely that the molecular bonds will be destabilized and the reaction completed.

The temperature is normally controlled automatically through the use of instrumentation that senses the temperature and automatically adjusts the amount of fuel and/or waste being fed. The temperature signal transmitted to the controller can be simultaneously transmitted to a recording device, referred to as a strip chart, and thereby continuously recorded. To fully assess the operation of the unit, it is important to know not only the exact location in the incinerator at which the temperature is being monitored but also the location of the design temperature.

(ii) Excess oxygen. It is important that the incinerator contain oxygen in excess of the stoichiometric amount necessary to convert the organic compounds to carbon dioxide and water vapor. If insufficient oxygen is present, then destabilized waste constituents could recombine to the same or other BDAT list organic compounds and potentially cause the scrubber water to contain higher concentrations of BDAT list constituents than would be the case for a well-operated unit.

In practice, the amount of oxygen fed to the incinerator is controlled by continuous sampling and analysis of the stack gas. If the amount of oxygen drops below the design value, then the analyzer transmits a signal to the valve controlling the air supply and thereby increases the flow of oxygen to the afterburner. The analyzer simultaneously transmits a signal to a recording device so that the amount of excess oxygen can be continuously recorded. Again, as with temperature, it is important to know the location at which the combustion gas is being sampled.

(iii) Carbon monoxide. Carbon monoxide is an important operating parameter because it provides an indication of the extent to which the waste organic constituents are being converted to carbon dioxide and water vapor. An increase in the carbon monoxide level indicates that greater amounts of organic waste constituents are unreacted or partially reacted. Increased carbon monoxide levels can result from insufficient excess oxygen, insufficient turbulence in the combustion zone, or insufficient residence time.

(iv) Waste feed rate. The waste feed rate is important to monitor because it is correlated to the residence time. The residence time is associated with a specific Btu energy value of the feed and a specific volume of combustion gas generated. Prior to incineration, the Btu value of the waste is determined through the use of a laboratory device known as a bomb calorimeter. The volume of combustion gas generated from the waste to be incinerated is determined from an analysis referred to as an ultimate analysis. This analysis determines the amount of elemental constituents present, which include carbon, hydrogen, sulfur, oxygen, nitrogen, and halogens. Using this analysis plus the total amount of air added, one can calculate the volume of combustion gas. After both the Btu content and the expected combustion gas volume have been determined, the feed rate can be fixed at the desired residence time. Continuous monitoring of the feed rate will determine whether the unit is being operated at a rate corresponding to the designed residence time.

(b) Rotary kiln. For this incineration, EPA will examine both the primary and secondary chamber in evaluating the design of a particular incinerator. Relative to the primary chamber, EPA's assessment of design will focus on whether sufficient energy is likely to be provided to the waste to volatilize the waste constituents. For the secondary chamber, analogous to the sole liquid injection incineration chamber, EPA will examine the same parameters discussed previously under liquid injection incineration. These parameters will not be discussed again here.

The particular design parameters to be evaluated for the primary chamber are kiln temperature, residence time, and revolutions per minute. Below is a discussion of why EPA believes these parameters to be important, as well as a discussion of how these parameters will be monitored during operation.

(i) Temperature. The primary chamber temperature is important, in that it provides an indirect measure of the energy input (i.e., Btu/hr) available for heating the waste. The higher the temperature is designed to be in a given kiln, the more likely it is that the constituents will volatilize. As discussed earlier under "Liquid injection," temperature should be continuously monitored and recorded. Additionally, it is important to know the location of the temperature sensing device in the kiln.

(ii) Residence time. This parameter is important in that it affects whether sufficient heat is transferred to a particular constituent in order for volatilization to occur. As the time that the waste is in the kiln is increased, a greater quantity of heat is transferred to the hazardous waste constituents. The residence time will be a function of the specific configuration of the rotary kiln, including the length and diameter of the kiln, the waste feed rate, and the rate of rotation. .

(iii) Revolutions per minute (RPM). This parameter provides an indication of the turbulence that occurs in the primary chamber of a rotary kiln. As the turbulence increases, the quantity of heat transferred to the waste would also be expected to increase. However, as the RPM value increases, the residence time decreases, resulting in a reduction of the quantity of heat transferred to the waste. This parameter needs to be carefully evaluated because it provides a balance between turbulence and residence time.

(c) Fluidized bed. As discussed previously in the section "Underlying principles of operation," the primary chamber accounts for almost all of the conversion of organic wastes to carbon dioxide, water vapor, and acid gas (if halogens are present). The secondary chamber will generally provide additional residence time for thermal oxidation of the waste constituents. Relative to the primary chamber, the parameters that the Agency will examine in assessing the effectiveness of the design are temperature, residence time, and bed pressure differential. The first two were included in the discussion of the rotary kiln and will not be discussed here. The last, bed pressure differential, is important in that it provides an indication of the amount of turbulence and therefore indirectly the amount of heat supplied to the waste. In general, as the pressure drop increases, both the turbulence and heat supplied increase. The pressure drop through the bed should be continuously monitored and recorded to ensure that the designed value is achieved.

(d) Fixed hearth. The design considerations for this incineration unit are similar to those for a rotary kiln with the exception that rate of rotation (i.e., RPM) is not an applicable design parameter. For the primary chamber of this unit, the parameters that the Agency will examine in assessing how well the unit is designed are the same as those discussed under "Rotary kiln"; for the secondary chamber (i.e., afterburner), the design and operating parameters of concern are the same as those previously discussed under "Liquid injection."

3.2.3 Chemical Precipitation

(1) Applicability and use of chemical precipitation. Chemical precipitation is used when dissolved metals are to be removed from solution. This technology can be applied to a wide range of wastewaters containing dissolved BDAT list metals and other metals as well. This treatment process has been practiced widely by industrial facilities since the 1940s.

(2) Underlying principles of operation. The underlying principle of chemical precipitation is that metals in wastewater are removed by the addition of a treatment chemical that converts the dissolved metal to a metal precipitate. This precipitate is less soluble than the original

metal compound and therefore settles out of solution, leaving a lower concentration of the metal present in the solution. The principal chemicals used to convert soluble metal compounds to the less soluble forms include lime ($Ca(OH)_2$), caustic (NaOH), sodium sulfide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulfide (FeS).

The solubility of a particular compound depends on the extent to which the electrostatic forces holding the ions of the compound together can be overcome. The solubility changes significantly with temperature; most metal compounds are more soluble as the temperature increases. Additionally, the solubility is affected by the other constituents present in a waste. As a general rule, nitrates, chlorides, and sulfates are more soluble than hydroxides, sulfides, carbonates, and phosphates.

An important concept related to treatment of the soluble metal compounds is pH. This term provides a measure of the extent to which a solution contains an excess of either hydrogen or hydroxide ions. The pH scale ranges from 0 to 14, with 0 being the most acidic, 14 representing the highest alkalinity or hydroxide ion (OH^-) content, and 7.0 being neutral.

When hydroxide is used, as is often the case, to precipitate the soluble metal compounds, the pH is frequently monitored to ensure that sufficient treatment chemicals are added. It is important to point out that pH is not a good measure of treatment chemical addition for compounds other than hydroxides; when sulfide is used, for example, facilities might use an oxidation-reduction potential (ORP) meter correlation to ensure that sufficient treatment chemical is used.

Following conversion of the relatively soluble metal compounds to metal precipitates, the effectiveness of chemical precipitation is a function of the physical removal, which usually relies on a settling process. A particle of a specific size, shape, and composition will settle at a specific velocity, as described by Stokes' Law. For a batch system, Stokes' Law is a good predictor of settling time because the pertinent particle parameters remain essentially constant. Nevertheless, in practice, settling time for a batch system is normally determined by empirical testing. For a continuous system, the theory of settling is complicated by factors such as turbulence, short-circuiting, and velocity gradients, thereby increasing the importance of the empirical tests.

(3) Description of the chemical precipitation process. The equipment and instrumentation required for chemical precipitation vary depending on whether the system is batch or continuous. Both operations are discussed below; a schematic of the continuous system is shown in Figure 3-5.

For a batch system, chemical precipitation requires only a feed system for the treatment chemicals and a second tank where the waste can be treated and allowed to settle. When lime is used, it is usually added to the reaction tank in a slurry form. In a batch system, the supernate is usually analyzed before discharge, thus minimizing the need for instrumentation.

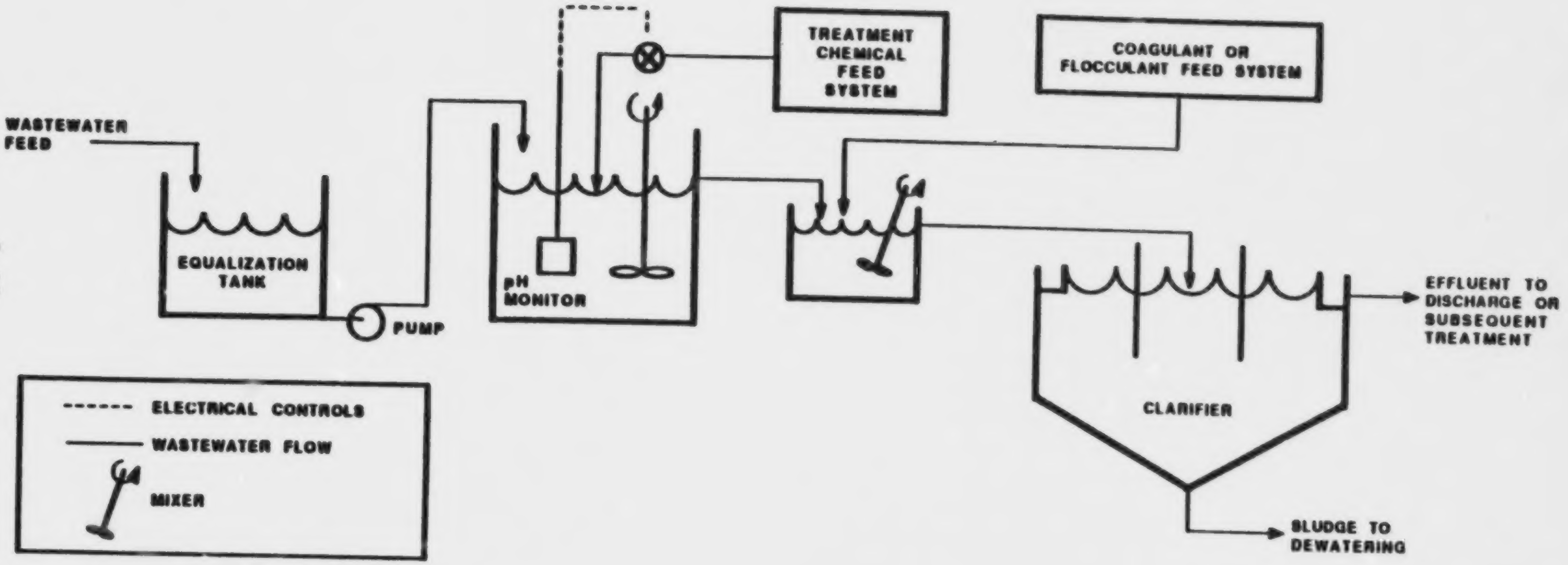

WASTEWATER FEED
EQUALIZATION TANK
PUMP
pH MONITOR
TREATMENT CHEMICAL FEED SYSTEM
COAGULANT OR FLOCCULANT FEED SYSTEM
CLARIFIER
EFFLUENT TO DISCHARGE OR SUBSEQUENT TREATMENT
SLUDGE TO DEWATERING
ELECTRICAL CONTROLS
WASTEWATER FLOW
MIXER

FIGURE 3-5 **CONTINUOUS CHEMICAL PRECIPITATION**

In a continuous system, additional tanks are necessary, as well as instrumentation to ensure that the system is operating properly. In this system, the first tank that the wastewater enters is referred to as an equalization tank. This is where the waste can be mixed to provide more uniformity, minimizing wide swings in the type and concentration of constituents being sent to the reaction tank. It is important to reduce the variability of the waste sent to the reaction tank because control systems inherently are limited with regard to the maximum fluctuations that can be managed.

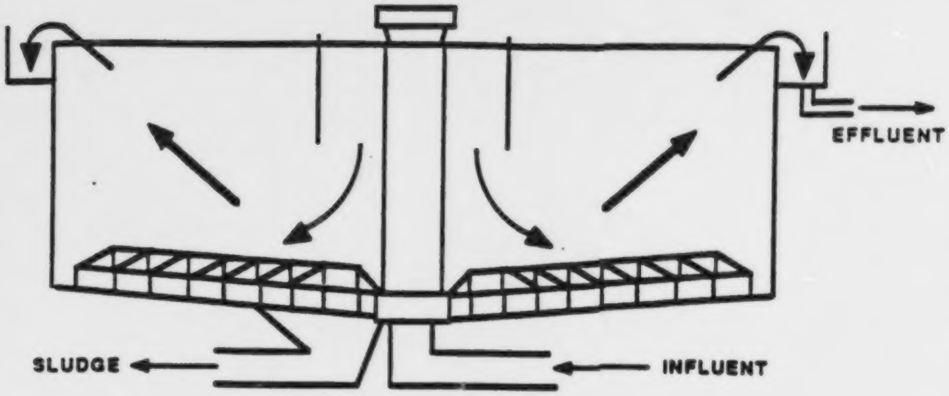
Following equalization, the waste is pumped to a reaction tank where treatment chemicals are added; this is done automatically by using instrumentation that senses the pH of the system and then pneumatically adjusts the position of the treatment chemical feed valve so that the design pH value is achieved. Both the complexity and the effectiveness of the automatic control system will vary depending on the variation in the waste and the pH range that is needed to properly treat the waste.

An important aspect of the reaction tank design is that the tank's contents be well mixed so that the waste and the treatment chemicals are both dispersed throughout the tank to ensure commingling of the reactant and the treatment chemicals. In addition, effective dispersion of the treatment chemicals throughout the tank is necessary to properly monitor and thereby control the amount of treatment chemicals added.

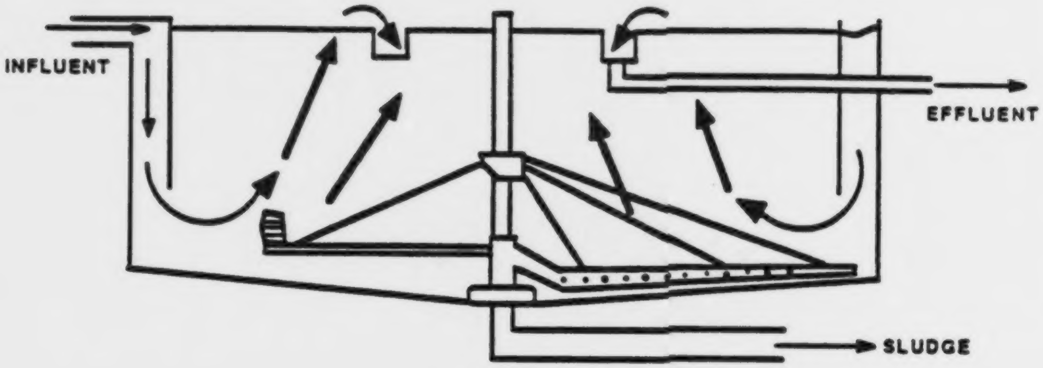
After the waste is reacted with the treatment chemical, it flows to a quiescent tank where the precipitate is allowed to settle and subsequently to be removed. Settling can be chemically assisted through the use of flocculating compounds. Flocculants increase the particle size and density of the precipitated solids, both of which increase the rate of settling. The particular flocculating agent that will best improve settling characteristics will vary depending on the particular waste; selection of the flocculating agent is generally accomplished by performing laboratory bench tests. Settling can be conducted in a large tank by relying solely on gravity or can be mechanically assisted through the use of a circular clarifier or an inclined separator. Schematics of the latter two separators are shown in Figures 3-6 and 3-7.

Filtration can be used for further removal of precipitated residuals both in cases where the settling system is underdesigned and in cases where the particles are difficult to settle. Polishing filtration is discussed in a separate technology section.

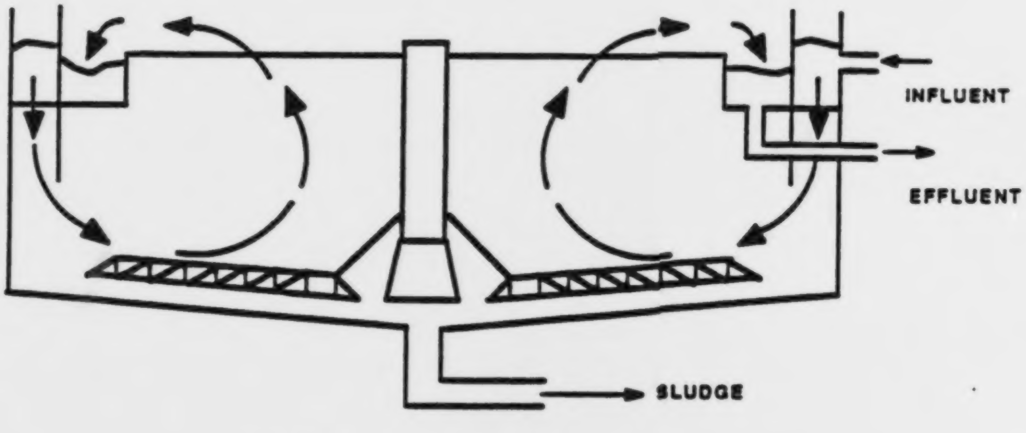
(4) Waste characteristics affecting performance. In determining whether chemical precipitation is likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA will examine the following waste characteristics: (1) the concentration and type of the metal(s) in the waste, (2) the concentration of total suspended solids (TSS), (3) the concentration of total dissolved solids (TDS), (4) whether the metal exists in the wastewater as a complex, and (5) the oil and grease content. These parameters affect the chemical


EFFLUENT
SLUDGE
INFLUENT

CENTER FEED CLARIFIER WITH SCRAPER SLUDGE REMOVAL SYSTEM


INFLUENT
EFFLUENT
SLUDGE

RIM FEED - CENTER TAKEOFF CLARIFIER WITH HYDRAULIC SUCTION SLUDGE REMOVAL SYSTEM


INFLUENT
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SLUDGE

RIM FEED - RIM TAKEOFF CLARIFIER

FIGURE 3-6
CIRCULAR CLARIFIERS

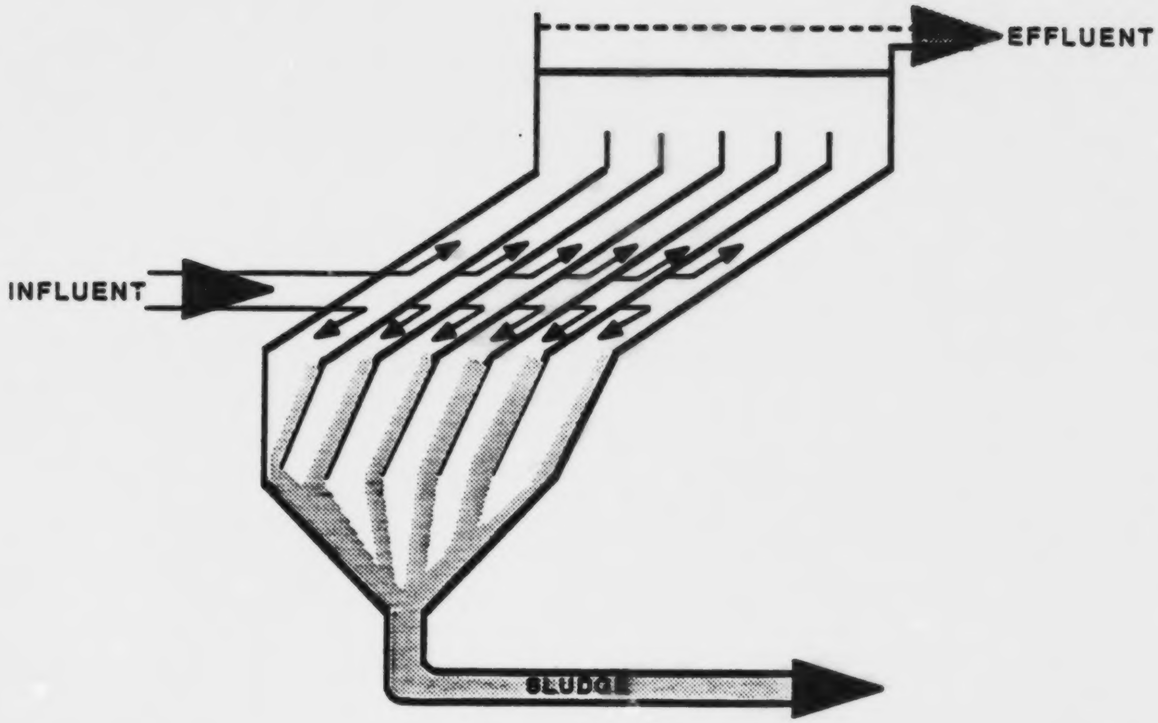
EFFLUENT
INFLUENT
SLUDGE

FIGURE 3-7

INCLINED PLATE SETTLER

reaction of the metal compound, the solubility of the metal precipitate, or the ability of the precipitated compound to settle.

(a) Concentration and type of metals. For most metals, there is a specific pH at which the metal hydroxide is least soluble. As a result, when a waste contains a mixture of many metals, it is not possible to operate a treatment system at a single pH that is optimal for the removal of all metals. The extent to which this situation affects treatment depends on the particular metals to be removed and their concentrations. One approach is to operate multiple precipitations, with intermediate settling, when the optimum pH occurs at markedly different levels for the metals present. The individual metals and their concentrations can be measured using EPA Method 6010.

(b) Concentration and type of total suspended solids (TSS). Certain suspended solid compounds are difficult to settle because of their particle size or shape. Accordingly, EPA will evaluate this characteristic in assessing the transfer of treatment performance. Total suspended solids can be measured by EPA Wastewater Test Method 160.2.

(c) Concentration of total dissolved solids (TDS). Available information shows that total dissolved solids can inhibit settling. The literature states that poor flocculation is a consequence of high TDS and shows that higher concentrations of total suspended solids are found in treated residuals. Poor flocculation can adversely affect the degree to which precipitated particles are removed. Total dissolved solids can be measured by EPA Wastewater Test Method 160.1.

(d) Complexed metals. Metal complexes consist of a metal ion surrounded by a group of other inorganic or organic ions or molecules (often called ligands). In the complexed form, the metals have a greater solubility and therefore may not be as effectively removed from solution by chemical precipitation. EPA does not have an analytical method to determine the amount of complexed metals in the waste. The Agency believes that the best measure of complexed metals is to analyze for some common complexing compounds (or complexing agents) generally found in wastewater for which analytical methods are available. These complexing agents include ammonia, cyanide, and EDTA. The analytical method for cyanide is EPA Method 9010, while the method for EDTA is ASTM Method D3113. Ammonia can be analyzed using EPA Wastewater Test Method 350.

(e) Oil and grease content. The oil and grease content of a particular waste directly inhibits the settling of the precipitate. Suspended oil droplets float in water and tend to suspend particles such as chemical precipitates that would otherwise settle out of the solution. Even with the use of coagulants or flocculants, the separation of the precipitate is less effective. Oil and grease content can be measured by EPA Method 9071.

(5) Design and operating parameters. The parameters that EPA will evaluate when determining whether a chemical precipitation system is well designed are (1) design value for treated metal concentrations, as well as other characteristics of the waste used for design purposes (e.g., total suspended solids); (2) pH; (3) residence time; (4) choice of

treatment chemical; (5) choice of coagulant/flocculant; and (6) mixing. The reasons for which EPA believes these parameters are important to a design analysis are cited below, along with an explanation of why other design criteria are not included in this analysis.

(a) Treated and untreated design concentrations. When determining whether to sample a particular facility, EPA pays close attention to the treated concentration that the system is designed to achieve. Since the system will seldom outperform its design, EPA must evaluate whether the design is consistent with best demonstrated practice.

The untreated concentrations that the system is designed to treat are important in evaluating any treatment system. Operation of a chemical precipitation treatment system with untreated waste concentrations in excess of design values can easily result in poor performance.

(b) pH. The pH is important because it can indicate that sufficient treatment chemical (e.g., lime) has been added to convert the metal constituents in the untreated waste to forms that will precipitate. The pH also affects the solubility of metal hydroxides and sulfides and thus directly impacts the effectiveness of removal. In practice, the design pH is determined by empirical bench testing, often referred to as "jar" testing. The temperature at which the "jar" testing is conducted is important since it also affects the solubility of the metal precipitates. Operation of a treatment system at temperatures above the design temperature can result in poor performance. In assessing the operation of a chemical precipitation system, EPA prefers to use continuous data on the pH and periodic temperature conditions throughout the treatment period.

(c) Residence time. Residence time is important because it impacts the completeness of the chemical reaction to form the metal precipitate and, to a greater extent, the amount of precipitate that settles out of solution. In practice, it is determined by "jar" testing. For continuous systems, EPA will monitor the feed rate to ensure that the system is operated at design conditions. For batch systems, EPA will want information on the design parameter used to determine sufficient settling time (e.g., total suspended solids).

(d) Choice of treatment chemical. A choice must be made as to what type of precipitating agent (i.e., treatment chemical) will be used. The factor that most affects this choice is the type of metal constituents to be treated. Other design parameters, such as pH, residence time, and choice of coagulant/flocculant agents, are based on the selection of the treatment chemical.

(e) Choice of coagulant/flocculant. This is important because these compounds improve the settling rate of the precipitated metals and allow smaller systems (i.e., those with a lower retention time) to achieve the same degree of settling as much larger systems. In practice, the choice of the best agent and the required amount is determined by "jar" testing.

(f) Mixing. The degree of mixing is a complex assessment that includes, the energy supplied, the time the material is mixed, and the related turbulence effects of the specific size and shape of the tank.

In its analysis, EPA will consider whether mixing is provided and whether the type of mixing device is one that could be expected to achieve uniform mixing. For example, EPA may not use data from a chemical precipitation treatment system in which an air hose was placed in a large tank to achieve mixing.

3.2.4 Sludge Filtration

(1) Applicability and use of sludge filtration. Sludge filtration, also known as sludge dewatering or cake-formation filtration, is a technology used on wastes that contain high concentrations of suspended solids, generally higher than 1 percent. The remainder of the waste is essentially water. Sludge filtration is applied to sludges, typically those that have settled to the bottom of clarifiers, for dewatering. After filtration, these sludges can be dewatered to 20 to 50 percent solids.

(2) Underlying principle of operation. The basic principle of filtration is the separation of particles from a mixture of fluids and particles by a medium that permits the flow of the fluid but retains the particles. As would be expected, larger particles are easier to separate from the fluid than are smaller particles. Extremely small particles, in the colloidal range, may not be filtered effectively and may appear in the treated waste. To mitigate this problem, the wastewater should be treated prior to filtration to modify the particle size distribution in favor of the larger particles, by the use of appropriate precipitants, coagulants, flocculants, and filter aids. The selection of the

appropriate precipitant or coagulant is important because it affects the particles formed. For example, lime neutralization usually produces larger, less gelatinous particles than does caustic soda precipitation. For larger particles that become too small to filter effectively because of poor resistance to shearing, shear resistance can be improved by the use of coagulants and flocculants. Also, if pumps are used to feed the filter, shear can be minimized by designing for a lower pump speed or by using a low-shear type of pump.

(3) Description of the sludge filtration process. For sludge filtration, settled sludge is either pumped through a cloth-type filter medium (such as in a plate and frame filter that allows solid "cake" to build up on the medium) or the sludge is drawn by vacuum through the cloth medium (such as on a drum or vacuum filter, which also allows the solids to build). In both cases the solids themselves act as a filter for subsequent solids removal. For a plate and frame type filter, solids are removed by taking the unit off line, opening the filter, and scraping the solids off. For the vacuum type filter, the cake is removed continuously. For a specific sludge, the plate and frame type filter will usually produce a drier cake than will a vacuum filter. Other types of sludge filters, such as belt filters, are also used for effective sludge dewatering.

(4) Waste characteristics affecting performance. The following characteristics of the waste will affect performance of a sludge filtration unit: (1) size of particles and (2) type of particles.

(a) Size of particles. The smaller the particle size, the more the particles tend to go through the filter medium. This is especially true for a vacuum filter. For a pressure filter (like a plate and frame), smaller particles may require higher pressures for equivalent throughput, since the smaller pore spaces between particles create resistance to flow.

(b) Type of particles. Some solids formed during metal precipitation are gelatinous in nature and cannot be dewatered well by cake-formation filtration. In fact, for vacuum filtration a cake may not form at all. In most cases, solids can be made less gelatinous by use of the appropriate coagulants and coagulant dosage prior to clarification, or after clarification but prior to filtration. In addition, the use of lime instead of caustic soda in metal precipitation will reduce the formation of gelatinous solids. The addition of filter aids, such as lime or diatomaceous earth, to a gelatinous sludge will help significantly. Finally, precoating the filter with diatomaceous earth prior to sludge filtration will assist in dewatering gelatinous sludges.

(5) Design and operating parameters. For sludge filtration, the following design and operating variables affect performance: (1) type of filter selected, (2) size of filter selected, (3) feed pressure, and (4) use of coagulants or filter aids.

(a) Type of filter. Typically, pressure type filters (such as a plate and frame) will yield a drier cake than will a vacuum type filter and will also be more tolerant of variations in influent sludge characteristics. Pressure type filters, however, are batch operations, so that when cake is built up to the maximum depth physically possible (constrained by filter geometry), or to the maximum design pressure, the filter is turned off while the cake is removed. A vacuum filter is a continuous device (i.e., cake discharges continuously), but will usually be much larger than a pressure filter with the same capacity. A hybrid device is a belt filter, which mechanically squeezes sludge between two continuous fabric belts.

(b) Size of filter. As with in-depth filters, the larger the filter, the greater its hydraulic capacity and the longer the filter runs between cake discharges.

(c) Feed pressure. This parameter impacts both the design pore size of the filter and the design flow rate. In treating waste, it is important that the design feed pressure not be exceeded; otherwise, particles may be forced through the filter medium, resulting in ineffective treatment.

(d) Use of coagulants. Coagulants and filter aids may be mixed with filter feed prior to filtration. Their effect is particularly significant for vacuum filtration since in this instance they may make the difference between no cake and a relatively dry cake. In a pressure filter, coagulants and filter aids will also significantly improve hydraulic capacity and cake dryness. Filter aids, such as diatomaceous earth, can be precoated on filters (vacuum or pressure) for sludges that are particularly difficult to filter. The precoat layer acts somewhat like an in-depth filter in that sludge solids are trapped in the precoat pore spaces. Use of precoats and most coagulants or filter aids significantly increases the amount of sludge solids to be disposed of. However, polyelectrolyte coagulant usage usually does not increase sludge volume significantly because the dosage is low.

3.2.5 Stabilization

Stabilization refers to a broad class of treatment processes that chemically reduce the mobility of hazardous constituents in a waste. Solidification and fixation are other terms that are sometimes used synonymously for stabilization or to describe specific variations within the broader class of stabilization. Related technologies are encapsulation and thermoplastic binding; however, EPA considers these technologies to be distinct from stabilization in that the operational principles are significantly different.

(1) Applicability and use of stabilization. Stabilization is used when a waste contains metals that will leach from the waste when it is contacted by water. In general, this technology is applicable to wastes containing BDAT list metals and having a high filterable solids content, low TOC content, and low oil and grease content. This technology is commonly used to treat residuals generated from treatment of electroplating wastewaters. For some wastes, an alternative to stabilization is metal recovery.

(2) Underlying principles of operation. The basic principle underlying this technology is that stabilizing agents and other chemicals are added to a waste to minimize the amount of metal that leaches. The

reduced leachability is accomplished by the formation of a lattice structure and/or chemical bonds that bind the metals to the solid matrix and thereby limit the amount of metal constituents that can be leached when water or a mild acid solution comes into contact with the waste material.

Two principal stabilization processes are used--cement-based and lime-based. A brief discussion of each is provided below. In both cement-based and lime/pozzolan-based techniques, the stabilizing process can be modified through the use of additives, such as silicates, that control curing rates or enhance the properties of the solid material.

(a) Portland cement-based process. Portland cement is a mixture of powdered oxides of calcium, silica, aluminum, and iron, produced by kiln burning of materials rich in calcium and silica at high temperatures (i.e., 1400 to 1500°C). When the anhydrous cement powder is mixed with water, hydration occurs and the cement begins to set. The chemistry involved is complex because many different reactions occur depending on the composition of the cement mixture.

As the cement begins to set, a colloidal gel of indefinite composition and structure is formed. Over a period of time, the gel swells and forms a matrix composed of interlacing, thin, densely packed silicate fibrils. Constituents present in the waste slurry (e.g., hydroxides and carbonates of various heavy metals) are incorporated into the interstices of the cement matrix. The high pH of the cement mixture tends to keep metals in the form of insoluble hydroxide and carbonate salts. It has been hypothesized that metal ions may also be incorporated into the crystal structure of the cement matrix, but this hypothesis has not been verified.

(b) Lime/pozzolan-based process. Pozzolan, which contains finely divided, noncrystalline silica (e.g., fly ash or components of cement kiln dust), is a material that is not cementitious in itself but becomes so upon the addition of lime. Metals in the waste are converted to silicates or hydroxides, which inhibit leaching. Additives, again, can be used to reduce permeability and thereby further decrease leaching potential.

(3) Description of the stabilization process. In most stabilization processes, the waste, stabilizing agent, and other additives, if used, are mixed and then pumped to a curing vessel or area and allowed to cure. The actual operation (equipment requirements and process sequencing) will depend on several factors such as the nature of the waste, the amount of waste, the location of the waste in relation to the disposal site, the particular stabilization formulation to be used, and the curing rate. After curing, the solid formed is recovered from the processing equipment and shipped for final disposal.

In instances where waste contained in a lagoon is to be treated, the material should first be transferred to mixing vessels where stabilizing agents are added. The mixed material is then fed to a curing pad or vessel. After curing, the solid formed is removed for disposal. Equipment commonly used also includes facilities to store waste and chemical additives. Pumps can be used to transfer liquid or light sludge wastes to the mixing pits and pumpable uncured wastes to the curing site. Stabilized wastes are then removed to a final disposal site.

Commercial concrete mixing and handling equipment generally can be used with wastes. Weighing conveyors, metering cement hoppers, and mixers similar to concrete batching plants have been adapted in some operations. Where extremely dangerous materials are being treated, remote-control and in-drum mixing equipment, such as that used with nuclear waste, can be employed.

(4) Waste characteristics affecting performance. In determining whether stabilization is likely to achieve the same level of performance on an untested waste as on a previously tested waste, the Agency will focus on the characteristics that inhibit the formation of either the chemical bonds or the lattice structure. The four characteristics EPA has identified as affecting treatment performance are the presence of (1) fine particulates, (2) oil and grease, (3) organic compounds, and (4) certain inorganic compounds.

(a) Fine particulates. For both cement-based and lime/pozzolan-based processes, the literature states that very fine solid materials (i.e., those that pass through a No. 200 mesh sieve, 74 um particle size) can weaken the bonding between waste particles and cement by coating the particles. This coating can inhibit chemical bond formation and decreases the resistance of the material to leaching.

(b) Oil and grease. The presence of oil and grease in both cement-based and lime/pozzolan-based systems results in the coating of waste particles and the weakening of the bonding between the particle and the stabilizing agent. This coating can inhibit chemical bond formation and thereby decrease the resistance of the material to leaching.

(c) Organic compounds. The presence of organic compounds in the waste interferes with the chemical reactions and bond formation, which inhibits curing of the stabilized material. This results in a stabilized waste that has decreased resistance to leaching.

(d) Sulfate and chlorides. The presence of certain inorganic compounds interferes with the chemical reactions, weakening bond strength and prolonging setting and curing time. Sulfate and chloride compounds may reduce the dimensional stability of the cured matrix, thereby increasing leachability potential.

Accordingly, EPA will examine these constituents when making decisions regarding transfer of treatment standards based on stabilization.

(5) Design and operating parameters. In designing a stabilization system, the principal parameters that are important to optimize so that the amount of leachable metal constituents is minimized are (1) selection of stabilizing agents and additives, (2) ratio of waste to stabilizing agents and other additives, (3) degree of mixing, and (4) curing conditions.

(a) Selection of stabilizing agents and other additives. The stabilizing agent and additives used will determine the chemistry and structure of the stabilized material and therefore will affect the leachability of the solid material. Stabilizing agents and additives must be carefully selected based on the chemical and physical characteristics of the waste to be stabilized. For example, the amount of sulfates in a waste must be considered when a choice is being made between a lime/pozzolan-based and a portland cement-based system.

To select the type of stabilizing agents and additives, the waste should be tested in the laboratory with a variety of materials to determine the best combination.

(b) Amount of stabilizing agents and additives. The amount of stabilizing agents and additives is a critical parameter in that sufficient stabilizing materials are necessary in the mixture to properly bind the waste constituents of concern, thereby making them less susceptible to leaching. The appropriate weight ratios of waste to stabilizing agent and other additives are established empirically by setting up a series of laboratory tests that allow separate leachate testing of different mix ratios. The ratio of water to stabilizing agent (including water in waste) will also impact the strength and leaching characteristics of the stabilized material. Too much water will cause low strength; too little will make mixing difficult and, more important, may not allow the chemical reactions that bind the hazardous constituents to be fully completed.

(c) Mixing. This parameter includes both the type and duration of mixing. Mixing is necessary to ensure homogeneous distribution of the waste and the stabilizing agents. Both undermixing and overmixing are undesirable. The first condition results in a nonhomogeneous mixture; therefore, areas will exist within the waste where waste particles are neither chemically bonded to the stabilizing agent nor physically held within the lattice structure. Overmixing, on the other hand, may inhibit gel formation and ion adsorption in some stabilization systems. As with the relative amounts of waste, stabilizing agent, and additives within the system, optimal mixing conditions generally are determined through laboratory tests. During treatment it is important to monitor the degree (i.e., type and duration) of mixing to ensure that it reflects design conditions.

(d) Curing conditions. Curing conditions include the duration of curing and the ambient curing conditions (temperature and humidity). The duration of curing is a critical parameter to ensure that the waste particles have had sufficient time in which to form stable chemical bonds and/or lattice structures. The time necessary for complete stabilization depends upon the waste type and the stabilization used. The performance of the stabilized waste (i.e., the levels of constituents in the leachate) will be highly dependent upon whether complete stabilization has occurred. Higher temperatures and lower humidity increase the rate of curing by increasing the rate of evaporation of water from the solidification mixtures. If temperatures are too high, however, the evaporation rate can be excessive, resulting in too little water being available for completion of the stabilization reaction. The duration of the curing process, which should also be determined during the design stage, typically will range between 7 and 28 days.

4. PERFORMANCE DATA BASE

This section discusses the available performance data associated with the demonstrated technologies for K087 waste. Performance data include the constituent concentrations in untreated and treated waste samples, the operating data collected during treatment of the sampled waste, design values for the treatment technologies, and data on waste characteristics that affect performance. EPA has presented all such data to the extent that they are available.

EPA's use of these data in determining the technologies that represent BDAT, and for developing treatment standards, is described in Sections 5 and 7, respectively.

4.1 BDAT List Organics

The Agency has data for five sets of untreated waste and kiln ash samples and six scrubber water samples from an EPA incineration facility that show treatment of BDAT list organic constituents in K087 waste. These analytical data, collected during a test burn using rotary kiln incineration, have been reported in the K087 onsite engineering report (USEPA 1988a), along with design and operating information on the treatment system. The analytical data are presented in Tables 4-1 through 4-3 at the end of this section. These data show total waste concentrations for all BDAT list constituents in the untreated waste (Table 4-1), the residual ash (Table 4-2), and the scrubber water (Table 4-3). TCLP leachate concentrations for metals in the ash are also shown (Table 4-2). Operating data collected during the test burn are presented and discussed in Appendix C.

4.2 BDAT List Metals

4.2.1 Wastewater

The Agency does not have performance data on treatment of BDAT list metals in the scrubber water generated by rotary kiln incineration of K087 waste. However, 11 data sets are available from treatment of BDAT list metals in a metal-bearing wastewater by chemical precipitation, primarily using lime as the treatment chemical, and sludge filtration. These performance data are presented in Table 4-4. They reflect total waste concentrations for BDAT list metals in the untreated and treated wastewater.

Based on the available information on waste characteristics that affect treatment performance, the Agency believes these data represent a level of performance that can be achieved using this same treatment on the K087 scrubber water. A comparison of the scrubber water data and the untreated metal-bearing wastewater data reveals that both wastes contain small, if any, concentrations of antimony, arsenic, barium, beryllium, mercury, selenium, thallium, and vanadium. Concentrations of cadmium, chromium, copper, lead, nickel, and zinc are, in most cases, significantly lower in the K087 scrubber water, making it likely that the scrubber water would be less difficult to treat. Other performance-related waste characterization data for both wastes were not available for comparison.

4.2.2 Nonwastewater

EPA does not have performance data on treatment of BDAT list metals in either the ash generated by rotary kiln incineration of K087 waste or the treatment sludge generated by precipitation of the K087 scrubber water. Industry, however, submitted performance data showing treatment of F006 waste (an electroplating sludge) by stabilization, the demonstrated technology for K087 nonwastewater. These F006 data, presented in Table 4-5, reflect total waste and TCLP leachate concentrations for BDAT list metals in the untreated waste and TCLP leachate concentrations for metals in the treated waste. The data represent F006 wastes from various electroplating industries, including auto part manufacturing, aircraft overhauling, zinc plating, small engine manufacturing, and circuit board manufacturing.

The Agency believes these F006 data can be used to represent the performance of stabilization on the treatment sludge that would be generated from treatment of K087 scrubber water. An analysis of the waste characteristics that affect stabilization performance indicates that the treatment sludge would be less difficult to treat than the F006 waste. The scrubber water data show that this residual contains metals at concentrations ranging from less than 0.0003 mg/l to 8.3 mg/l, with the highest concentration being 8.3 mg/l for lead (see Table 4-3 and the accuracy-corrected data in Table B-4). Precipitation of this waste would yield a precipitated residue with an estimated concentration of up to 160 mg/l for lead, lower concentrations for the other metals present, and a water content and filterable solids concentration similar to those of the F006 wastes. A review of the F006 wastes shows that they contain metals at concentrations ranging up to 42,900 ppm.

The Agency believes the F006 data can also be used to represent the performance of stabilization on the K087 ash. EPA expects that the ash is easier to stabilize because such ash residuals contain metals in the form of oxides, which have been shown to leach at lower concentrations than the typical F006 hydroxides.

Other stabilization data, available to EPA, can be found in the Administrative Record. These data were eliminated from further consideration as sources for transferring data to develop treatment standards because of one or a combination of the reasons provided below:

1. The waste treated was less similar to the K087 ash or expected precipitated residuals than the waste for which performance data are presented;
2. The performance data do not show substantial treatment for the constituents to be regulated (selected in Section 6);
3. Design and operating data, or the lack of such data, do not enable the Agency to ascertain whether the treatment system was well designed and well operated; or
4. The measure of performance is not consistent with EPA's approach in evaluating treatment of metals by stabilization; e.g., EP levels are given rather than TCLP leachate levels.

Table 4-1 Analytical Results for K087 Untreated Waste
Collected Prior to Treatment by Rotary Kiln Incineration

Constituent/parameter (units)	Concentration				
	Sample Set #				
	1	2	3	4	5
BDAT Volatile Organics (mg/kg)					
Benzene	17	19	5.6	212	170
Methyl ethyl ketone	<2.0	<2.1	<2.0	<10	<10
Toluene	17	17	5.0	152	130
Xylenes	21	23	3.0	123	121
BDAT Semivolatile Organics (mg/kg)					
Acenaphthalene	11000	12000	10000	13000	10000
Anthracene	7500	8100	7100	8100	6700
Benz(a)anthracene	5700	5900	5600	7500	5400
Benzo(b)fluoranthene	3200	<1010	3100	<982	5300
Benzo(k)fluoranthene	3100	7500	3100	9300	<1026
Benzo(a)pyrene	4100	4300	4100	5400	3800
Chrysene	5100	5300	5100	6500	4700
para-Cresol	1600	1600	1300	1900	1200
Fluoranthene	11000	12000	11000	<982	11000
Fluorene	7600	7900	7000	9300	7000
Indeno(1,2,3-cd)pyrene	2100	2500	2300	3100	2100
Naphthalene	64000	66000	64000	81000	63000
Phenanthrene	34000	34000	15000	41000	15000
Phenol	1600	1500	1200	1800	1200
Pyrene	9100	5900	8000	9700	8100
BDAT Metals (mg/kg)^a					
Antimony	<2.0	<2.0	<2.0	<2.0	<2.0
Arsenic	6.1	6.1	5.5	1.9	5.2
Barium	<20	<20	<20	<20	<20
Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium	1.7	2.1	2.1	1.7	1.9
Chromium	<2.0	<2.0	<2.0	<2.0	<2.0
Copper	3.2	4.5	3.2	<2.5	2.6
Lead	85	80	72	64	69
Mercury	2.9	3.6	3.8	4.2	3.3
Nickel	<4.0	4.6	<4.0	<4.0	<4.0
Selenium	1.2	1.6	1.3	1.4	1.2
Silver	<5.0	<5.0	<5.0	<5.0	<5.0
Thallium	2.7	2.3	2.2	2.1	2.2
Vanadium	<5.0	<5.0	<5.0	<5.0	<5.0
Zinc	63	63	58	50	66

Table 4-1 (Continued)

Constituent/parameter (units)	Concentration Sample Set # 1	2	3	4	5
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide	22.8	18.2	21.1	22.0	17.9
Fluoride	0.38	-	-	-	0.18
Sulfide	323	320	275	293	302
Non-BDAT Volatile Organics (mg/kg)					
Styrene	12	12	3.4	26	71
Non-BDAT Semivolatile Organics (mg/kg)					
Dibenzofuran	5300	5600	5200	6800	5000
2-Methylnaphthalene	7000	6900	6300	9400	6200
Other Parameters					
Ash content (%)	2.9	3.4	9.7	3.7	2.7
Heating value (Btu/lb)	15095	14898	14823	15336	14959
Percent water (%)	5.70	10.31	11.26	7.72	6.60
Total halogens as chlorine (%)	0.033	0.023	0.026	0.045	0.057
Total organic carbon (%)	83.67	76.38	84.27	79.10	85.57
Total organic halides (mg/kg)	27.0	28.0	29.3	87.7	25.8
Total solids (%)[b]	87.7	90.5	91.1	89.7	86.5
Viscosity[c]	-	-	-	-	-
Elemental constituents (%)					
Carbon	83.80	81.90	84.01	66.36	77.54
Hydrogen	5.62	5.14	5.27	6.46	5.97
Nitrogen	1.13	1.06	1.03	0.82	0.96
Oxygen	9.13	11.94	10.25	26.59	15.71

- = Not analyzed.

ND = Not detected; estimated detection limit has not been determined.

Note: This table shows concentrations or maximum potential concentrations in the untreated waste for all constituents detected in the untreated waste or detected in the residuals generated by treatment of the waste. EPA analyzed the untreated waste for all the BDAT list constituents that are listed in Table D-1.

[a] Results have been reported on a wet weight basis.

[b] Total solids results are biased low because of test complications arising from waste matrix.

[c] Because of the high concentration of solids in the waste, viscosity values could not be determined.

Reference: USEPA 1988a.

Table 4-2 Analytical Results for Kiln Ash Generated by Rotary Kiln Incineration of K087 Waste

Constituent/parameter (units)	Concentration				
	Sample Set #				
	1	2	3	4	5
BDAT Volatile Organics (μg/kg)					
Benzene	<25	<25	<25	<25	<25
Methyl ethyl ketone	<25	<25	<25	<25	<25
Toluene	150	85	<25	<25	190
Xylenes	<25	<25	<25	<25	<25
BDAT Semivolatile Organics (μg/kg)					
Acenaphthalene	<1000	<1000	<1000	<1000	<1000
Anthracene	<1000	<1000	<1000	<1000	<1000
Benz(a)anthracene	<1000	<1000	<1000	<1000	<1000
Benzo(b)fluoranthene	<1000	<1000	<1000	<1000	<1000
Benzo(k)fluoranthene	<1000	<1000	<1000	<1000	<1000
Benzo(a)pyrene	<1000	<1000	<1000	<1000	<1000
Chrysene	<1000	<1000	<1000	<1000	<1000
para-Cresol	<1000	<1000	<1000	<1000	<1000
Fluoranthene	<1000	<1000	<1000	<1000	<1000
Fluorene	<1000	<1000	<1000	<1000	<1000
Indeno(1,2,3-cd)pyrene	<1000	<1000	<1000	<1000	<1000
Naphthalene	<1000	<1000	<1000	<1000	<1000
Phenanthrene	<1000	<1000	<1000	<1000	<1000
Phenol	<1000	<1000	<1000	<1000	<1000
Pyrene	<1000	<1000	<1000	<1000	<1000
BDAT Metals (mg/kg)					
Antimony	<3.2	<2.0	<2.0	<2.0	<3.2
Arsenic	9.9	11	6.7	12	5.3
Barium	317	56	53	41	63
Beryllium	0.60	<0.5	<0.5	<0.5	0.36
Cadmium	<0.40	<1.0	<1.0	<1.0	<0.40
Chromium	34	5.2	2.2	2.1	7.6
Copper	746	44	43	50	94
Lead	44	8.2	8.3	5.9	7.2
Mercury	<0.10	2.8	2.9	3.3	<0.1
Nickel	10	<4.0	<4.0	<4.0	4.5
Selenium	1.4	1.6	<0.50	5.9	<0.5
Silver	<0.60	<5.0	<5.0	<5.0	<6.0
Thallium	<1.0	<1.0	<1.0	<1.0	<1.0
Vanadium	17	9.7	6.6	8.1	10
Zinc	50	13	13	12	21

Table 4-2 (Continued)

Constituent/parameter (units)	Concentration				
	Sample Set #				
	1	2	3	4	5
BDAT TCLP: Metals (μg/l)					
Antimony	425	<20	<20	<20	<32
Arsenic	96	33	25	19	43
Barium	609	344	547	641	546
Beryllium	3.3	<5.0	<5.0	<5.0	2.5
Cadmium	<4.0	<10	<10	<10	<4.0
Chromium	62	<20	<20	<20	8.7
Copper	<6.0	52	1110	346	497
Lead	29	40	53	20	106
Mercury	<0.2	<0.30	<0.30	<0.30	<0.2
Nickel	93	<40	<40	<40	16
Selenium	<50	7.3	<5.0	<5.0	<5.0
Silver	<6.0	<50	<50	<50	<6.0
Thallium	<10	<10	<10	<10	<500
Vanadium	<30	<50	<50	<50	8.3
Zinc	169	202	218	288	256
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide	0.74	<0.50	<0.50	<0.50	<0.50
Fluoride	<1.0	-	-	-	<0.25
Sulfide	35.5	36.3	144	116	11.0
Non-BDAT Volatile Organics (μg/kg)					
Styrene	<25	<25	<25	<25	<25
Non-BDAT Semivolatile Organics (μg/kg)					
Dibenzofuran	<1000	<1000	<1000	<1000	<1000
2-Methylnaphthalene	<1000	<1000	<1000	<1000	<1000
Other Parameters (mg/kg)					
Total organic carbon	350000	553000	402000	316000	244000
Total chlorides	9.7	6.8	14.1	14.6	16.0
Total organic halides	375	18.3	32.1	19.8	133

- = Not analyzed.

Note: This table shows the concentrations or maximum potential concentrations in the kiln ash for all constituents that were detected in the untreated waste or detected in residuals generated from treatment of the waste. EPA analyzed the kiln ash for all the BDAT list constituents that are listed in Table D-2.

Reference: USEPA 1988a.

Table 4-3 Analytical Results for Scrubber Water Generated by Rotary Kiln Incineration of K087 Waste

Constituent/parameter (units)	Concentration Sample[a] 1	2	3	4	5	6
BDAT Volatile Organics (μg/l)						
Benzene	<5	<5	<5	<5	<5	<5
Methyl ethyl ketone	14	<10	<10	<10	<10	<10
Toluene	<5	8	<5	<5	<5	<5
Xylenes	<5	<5	<5	<5	<5	<5
BDAT Semivolatile Organics (μg/l)						
Acenaphthalene	<10	<10	<10	<10	<10	<10
Anthracene	<10	<10	<10	<10	<10	<10
Benz(a)anthracene	<10	<10	<10	<10	<10	<10
Benzo(b)fluoranthene	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	<10	<10	<10	<10	<10	<10
Benzo(a)pyrene	<10	<10	<10	<10	<10	<10
Chrysene	<10	<10	<10	<10	<10	<10
para-Cresol	<10	<10	<10	<10	<10	<10
Fluoranthene	<10	<10	<10	<10	<10	<10
Fluorene	<10	<10	<10	<10	<10	<10
Indeno(1,2,3-cd)pyrene	<10	<10	<10	<10	<10	<10
Naphthalene	<10	<10	<10	<10	<10	<10
Phenanthrene	<10	<10	<10	<10	<10	<10
Phenol	<10	<10	<10	<10	<10	<10
Pyrene	<10	<10	<10	<10	<10	<10
BDAT Metals (μg/l)						
Antimony	<32	<33	<20	39	<20	<32
Arsenic	211	191	148	257	300	342
Barium	65	350	302	340	290	102
Beryllium	<1.0	1.3	<5.0	<5.0	<5.0	<1.0
Cadmium	26	15	21	41	42	51
Chromium	306	304	155	236	255	259
Copper	1050	1100	948	1240	1160	1240
Lead	5610	7000	3240	4780	5610	4840
Mercury	0.23	<0.20	0.48	0.33	0.30	0.40
Nickel	<11	<11	<40	<40	<40	<11
Selenium	81	61	5.7	83	87	87
Silver	<6.0	<7.0	<50	<50	<50	<6.0
Thallium	126	109	77	108	96	136
Vanadium	15	12	<50	<50	<50	18
Zinc	2250	2040	1740	2910	2670	2960

Table 4-3 (Continued)

Constituent/parameter (units)	Concentration					
	Sample[a]					
	1	2	3	4	4	6
BDAT Inorganics Other Than Metals (mg/l)						
Cyanide	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoride	3.38	2.99	2.38	-	-	3.54
Sulfide	<1.0	<1.0	11.9	<1.0	<1.0	<1.0
Non-BDAT Volatile Organics (μg/l)						
Styrene	<5	<5	<5	<5	<5	<5
Non BDAT Semivolatile Organics (μg/l)						
Dibenzofuran	<10	<10	<10	<10	<10	<10
2-Methylnaphthalene	<10	<10	<10	<10	<10	<10
Other Parameters						
Total organic carbon (mg/l)	37.9	26.1	88.9	148	111	94.1
Total solids (mg/l)	2240	2080	1910	2350	2480	2720
Total chlorides (mg/l)	51.3	57.9	48.5	51.0	58.3	56.0
Total organic halides (μg/l)	33.7	33.2	48.7	23.3	27.6	27.4

- = Not analyzed.

Note: This table shows concentrations or maximum potential concentrations in the scrubber water for all constituents detected in the untreated waste or detected in residuals generated from treatment of the waste. EPA analyzed the scrubber water for all the BDAT list constituents that are listed in Table D-3.

[a] Scrubber water samples are not assigned a sample set number. See the K087 OER (USEPA 1988a) for specific collection times.

Reference: USEPA 1988a.

Table 4 4 Performance Data for Chemical Precipitation
and Sludge Filtration of a Metal Bearing Wastewater Sampled by EPA

Constituent/parameter	Concentration (ppm)							
	Sample Set #1		Sample Set #2		Sample Set #3		Sample Set #4	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals								
Antimony	<10	<1	<10	<1	<10	<1	<10	-
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Barium	<10	<1	<10	<1	<10	3.5	<10	<10
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<2
Cadmium	13	<0.5	10	<0.5	<5	<0.5	<5	<5
Chromium (hexavalent)[a]	893	0.011	807	0.190	775	-[a]	0.6	0.042
Chromium (total)	2,581	0.12	2,279	0.12	1,990	0.20	556	0.10
Copper	138	0.21	133	0.15	133	0.21	88	0.07
Lead	64	<0.01	54	<0.01	<10	<0.01	<10	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.1	<1	<1
Nickel	471	0.33	470	0.33	16,330	0.33	6,610	0.33
Selenium	<10	<1	<10	<1	<10	<1	<10	<10
Silver	<2	<0.2	2	<0.2	<2	<0.3	<2	<2
Thallium	<10	<1	<10	<1	<10	<1	<10	<10
Zinc	116	0.125	4	0.115	3.9	0.140	84	1.62
Other Parameters								
Total organic carbon	2700		2800		500		2900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	2500		3600		0		900	

Table 4-4 (Continued)

Constituent/parameter	Concentration (ppm)							
	Sample Set #5		Sample Set #6		Sample Set #7		Sample Set #8	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals								
Antimony	<10	<1	<10	<1	<10	<1	<10	<1
Arsenic	<1	<0.1	<1	<0.1	<1	<0.1	<1	<0.1
Barium	<10	<1	<10	<2	<10	<1	<10	<1
Beryllium	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Cadmium	<5	<0.5	<5	<0.5	10	<0.5	<5	<0.5
Chromium (hexavalent)	917	0.058	734	_a	769	0.121	0.13	<0.01
Chromium (total)	2,236	0.11	2,548	0.10	2,314	0.12	831	0.15
Copper	91	0.14	149	0.12	72	0.16	217	0.16
Lead	18	<0.01	<10	<0.01	108	<0.01	212	<0.01
Mercury	1	<0.1	<1	<0.1	<1	<0.01	<1	<0.1
Nickel	1,414	0.310	588	0.33	476	0.40	669	0.36
Selenium	<10	<1	<10	<1	<10	<1	<10	<1
Silver	<2	<0.2	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1	<10	<1	<10	<1	<10	<1
Zinc	71	0.125	4	0.095	171	0.115	151	0.130
Other Parameters								
Total organic carbon	200		700		3400		5900	
Total solids	-		-		-		-	
Total chlorides	-		-		-		-	
Total organic halides	0		700		1900		800	

Table 4-4 (Continued)

Constituent/parameter	Concentration (ppm)					
	Sample Set #9		Sample Set #10		Sample Set #11	
	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate	Treatment tank composite	Filtrate
BDAT Metals						
Antimony	<10	<1	<10	<1	<10	<1.00
Arsenic	<1	<0.1	<1	<0.1	<1	<0.10
Barium	<10	<1	<10	<1	<12	<1.00
Beryllium	<2	<0.2	<2	<0.2	<2	<0.20
Cadmium	<5	<0.5	<5	<0.5	23	<5
Chromium (hexavalent)	0.07	0.041	0.08	0.106	0.30	<0.01
Chromium (total)	939	0.10	395	0.12	617	0.18
Copper	225	0.08	191	0.14	137	0.24
Lead	<10	<0.01	<10	<0.01	136	<0.01
Mercury	<1	<0.1	<1	<0.1	<1	<0.10
Nickel	940	0.33	712	0.33	382	0.39
Selenium	<10	<1.0	<10	<1	<10	<1.00
Silver	<2	<0.2	<2	<0.2	<2	<0.2
Thallium	<10	<1.0	<10	<1	<10	<1.00
Zinc	5	0.06	5	0.070	135	0.100
Other Parameters						
Total organic carbon	2100		0		52	
Total solids	-		-		-	
Total chlorides	-		-		-	
Total organic halides	0		<300		300	

- = Not analyzed.

Note: Design and operating parameters are as follows:
pH during chromium reduction - 8.5 to 9.0.
Reducing agent - ferrous iron.
Ratio of reducing agent to hexavalent chromium - 3.2 to 10.
pH during chemical precipitation - 8 to 10.
Precipitation agent - lime.
Filter type - vacuum filter.

[a] Hexavalent chromium was actually treated by chromium reduction prior to chemical precipitation and sludge filtration.

Reference: USEPA 1986c.

Table 4-5 Performance Data for Stabilization of F006 Waste

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Arsenic	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.88
	Treated TCLP[a]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
	Treated TCLP[b]	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
Barium	Untreated total	36.4	21.6	85.5	17.2	14.3	24.5	12.6	15.3	19.2
	Untreated TCLP	0.08	0.32	1.41	0.84	0.38	0.07	0.04	0.53	0.28
	Treated TCLP[a]	0.12	0.50	0.33	0.20	0.31	0.30	0.04	0.32	0.19
	Treated TCLP[b]	-	0.42	0.31	0.23	0.19	0.33	0.14	0.27	0.08
Cadmium	Untreated total	1.3	31.3	67.3	1.30	720	7.28	5.39	5.81	5.04
	Untreated TCLP	0.01	2.21	1.13	0.22	23.6	0.3	0.06	0.18	0.01
	Treated TCLP[a]	0.01	0.50	0.06	0.01	3.23	0.02	0.01	0.01	<0.01
	Treated TCLP[b]	-	0.01	0.02	0.01	0.01	0.01	0.01	0.01	<0.01
Chromium	Untreated total	1270	755	716	110	12200	3100	42900	47.9	644
	Untreated TCLP	0.34	0.76	0.43	0.18	25.3	38.7	360	0.04	0.01
	Treated TCLP[a]	0.51	0.40	0.08	0.23	0.25	0.21	3.0	0.10	0.03
	Treated TCLP[b]	-	0.39	0.20	0.30	0.38	0.76	1.21	0.2	0.21
Copper	Untreated total	40.2	7030	693	1510	160	1220	10600	17600	27400
	Untreated TCLP	0.15	368	1.33	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP[a]	0.20	5.4	1.64	0.30	0.20	0.21	0.40	0.50	3.18
	Treated TCLP[b]	-	0.25	1.84	0.27	0.29	0.20	0.42	0.32	0.46
Lead	Untreated total	35.5	409	25.7	88.5	52	113	156	169	24500
	Untreated TCLP	0.26	10.7	0.26	0.45	0.45	3.37	1.0	4.22	50.2
	Treated TCLP[a]	0.30	0.40	0.30	0.30	0.24	0.30	0.30	0.31	2.39
	Treated TCLP[b]	-	0.36	0.41	0.34	0.36	0.36	0.38	0.37	0.27

Table 4-5 (Continued)

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Mercury	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
	Treated TCLP[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Treated TCLP[b]	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	Untreated total	435	989	259	37	701	19400	13000	23700	5730
	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP[a]	0.04	1.5	0.23	0.10	0.53	16.5	0.40	15.7	1.09
	Treated TCLP[b]	-	0.03	0.15	0.02	0.04	0.05	0.10	0.04	0.02
Selenium	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.45
	Treated TCLP[a]	0.06	0.06	0.07	0.08	0.04	0.05	0.04	0.07	<0.01
	Treated TCLP[b]	-	0.11	0.11	0.14	0.09	0.11	0.07	0.07	<0.01
Silver	Untreated total	2.3	6.62	39	9.05	5.28	4.08	12.5	8.11	19.1
	Untreated TCLP	0.01	0.14	0.02	0.16	0.08	0.12	0.05	0.31	<0.01
	Treated TCLP[a]	0.03	0.03	0.20	0.03	0.04	0.03	0.03	0.03	<0.01
	Treated TCLP[b]	-	0.05	0.05	0.04	0.06	0.05	0.05	0.05	<0.01
Zinc	Untreated total	1560	4020	631	90200	35900	27800	120	15700	322
	Untreated TCLP	0.16	219	5.41	2030	867	1200	0.62	650	1.29
	Treated TCLP[a]	0.03	36.9	0.05	32	3.4	36.3	0.02	4.54	0.07
	Treated TCLP[b]	-	0.01	0.03	0.04	0.03	0.04	0.02	0.02	<0.01

Binding agent: cement kiln dust.

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Note: Waste samples are from the following industries: set #1, unknown; set #2, auto part manufacturing; set #3, aircraft overhauling; set #4, zinc plating; set #5, unknown; set #6, small engine manufacturing; set #7, circuit board manufacturing; set #8, unknown; and set #9, unknown.

Reference: CWM Technical Note 87-117, Table 1 (CWM 1987).

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section explains EPA's determination of the best demonstrated available technology (BDAT) for K087 waste. As discussed in Section 1, the BDAT for a waste must be the "best" of the "demonstrated" technologies; the BDAT must also be "available." In general, the technology that constitutes "best" is determined after screening the available data from each demonstrated technology, adjusting these data for accuracy, and comparing the performance of each technology to that of the others. If only one technology is identified as demonstrated, this technology is considered "best." To be "available," a technology (1) must be commercially available and (2) must provide substantial treatment.

5.1 BDAT List Organics

The technologies identified as demonstrated on the organics in K087 waste are fuel substitution, incineration, and recycling.* The Agency has performance data only for rotary kiln incineration (presented in Section 4 and adjusted for accuracy in Appendix B). These data meet all the screening criteria outlined in Section 1.2.6(1). First, the data reflect a well-designed, well-operated system for all data points (see Appendix C). Second, sufficient QA/QC information is available to determine the true values of the analytical results for the treated residuals. Third, the measure of performance is consistent with

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* Recycling may not be feasible for all generators of K087 waste (refer to Section 3.2).

EPA's approach in evaluating the treatment of organics; i.e., total waste concentrations are given for BDAT list organics in the residual ash and scrubber water.

Because the performance data from rotary kiln incineration are the only data available for treatment of K087 waste, EPA is not able to perform an ANOVA test (see Appendix A) on the data to compare the three demonstrated technologies to determine which is best. However, since recycling does not result in a residual to be land disposed, EPA would consider it "best." Of fuel substitution and rotary kiln incineration, EPA does not believe that the former would perform better because (1) the performance data from rotary kiln incineration indicate that little additional treatment of organics can be accomplished, and (2) the temperatures and residence times of fuel substitution do not generally exceed those of rotary kiln incineration.

Both recycling and rotary kiln incineration are "available" because (1) neither process is proprietary or patented and thus both are commercially available, and (2) both substantially diminish the toxicity of the waste or significantly reduce the likelihood that hazardous constituents will migrate from the waste, as explained below.

For rotary kiln incineration, EPA believes that the number of constituents treated and the associated reductions achieved represent substantial treatment. For example, naphthalene concentrations ranging from 63,000 to 81,000 mg/kg were reduced to less than 1.2 mg/kg in the ash and 0.010 mg/l in the scrubber water; phenanthrene concentrations of

15,000 to 41,000 mg/kg were reduced to less than 1.2 mg/kg in the ash and 0.010 mg/l in the scrubber water; and benzene concentrations up to 212 mg/kg were reduced to less than 0.026 mg/kg in the ash and 0.005 mg/l in the scrubber water. (See the performance data in Tables 4-1 through 4-3 and the corresponding accuracy-corrected data in Appendix B.)

Recycling clearly provides substantial treatment because there are no residuals. The Agency, however, is establishing rotary kiln incineration as BDAT for the purpose of setting treatment standards because sufficient data are not available as to ascertain whether recycling is demonstrated for all K087 generators (see Section 3.2).

5.2 BDAT List Metals

Rotary kiln incineration and subsequent treatment of the scrubber water, as noted in Section 3, result in wastewater and nonwastewater residuals that contain metals which may require further treatment prior to land disposal.

5.2.1 Wastewater

For metals in K087 wastewater, the only identified demonstrated treatment is chemical precipitation, followed by settling or, alternatively, by sludge filtration. Performance data for a metal-bearing wastewater are available for chemical precipitation, using lime as the treatment chemical, and sludge filtration, as discussed in Section 4.2.1. The Agency does not expect the use of other treatment chemicals to improve the level of performance. Thus, chemical precipitation using lime as the treatment chemical and sludge filtration are "best."

Chemical precipitation, using lime, and sludge filtration are "available" because such treatment is commercially available and would provide substantial treatment for the K087 scrubber water. Having screened the data, EPA based its determination of substantial treatment on the fact that there were significant reductions in the concentrations of cadmium, chromium, copper, lead, nickel, and zinc in the metal-bearing wastewater for which data are available. (The treated data values are adjusted for accuracy in Appendix B.)

As chemical precipitation, using lime, followed by sludge filtration is demonstrated, best, and available for metals in K087 scrubber waters, this treatment represents BDAT for metals in K087 wastewaters.

5.2.2 Nonwastewater

For metals in K087 nonwastewater (i.e., ash or precipitated residuals from treatment of K087 scrubber water), the only identified demonstrated technology is stabilization. Performance data are available for stabilization of F006 waste using cement kiln dust as the binding agent as discussed in Section 4.2.2. The Agency does not expect that use of other binders would improve the level of performance. Thus, stabilization using cement kiln dust as the binding agent is "best."

Stabilization is "available" because it is commercially available and it substantially reduces the likelihood that hazardous constituents will migrate from the waste. EPA's determination of substantial treatment is discussed below.

In screening the performance data, the Agency determined whether any data points should be deleted on the basis that they do not represent a well-designed and well-operated system; EPA deleted data points from the less effective mix ratio used in treating the sample sets. Specifically, EPA determined that a mix ratio of 0.5 was most effective for wastes in Sample Sets 2, 4, 5, 6, 7, 8, and 9, and that a mix ratio of 0.2 was effective for wastes in Sample Sets 1 and 3.

The Agency deleted other data points for individual metal constituents for one of the following reasons: (1) the treated concentration was higher than the untreated concentration; (2) sufficient information was not available on the untreated concentration to determine treatment effectiveness; (3) the untreated leachate concentration was already at a low level where meaningful treatment could not be determined; and (4) the treated level of performance after correcting the results for accuracy could be attributed solely to dilution from the binding reagent. (Table B-8 in Appendix B shows accuracy-corrected values for all treated waste data points; this table also indicates the specific reasons for data point deletion.) Table 5-1 shows the remaining data. EPA's determination of substantial treatment is based on observations of the following reductions in the TCLP leachate concentrations of metals in the F006 waste: up to 23 mg/l for cadmium, 358 mg/l for chromium, 49 mg/l for lead, 729 mg/l for nickel, and 0.25 mg/l for silver.

As stabilization using cement kiln dust as a binder is demonstrated, best, and available for BDAT list metals in K087 nonwastewater, stabilization represents BDAT.

Table 5-1 TCLP Performance Data for Stabilization of F006 Waste After Screening and Accuracy Correction of Treated Values

Constituent	Stream	Concentration (ppm) Sample Set # 1[a]	2[b]	3[a]	4[b]	5[b]	6[b]	7[b]	8[b]	9[b]
Arsenic	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Barium	Untreated TCLP	--	--	1.41	0.84	0.38	--	--	0.53	0.28
	Treated TCLP	--	--	0.34	0.25	0.21	--	--	0.29	0.09
Cadmium	Untreated TCLP	--	2.21	1.13	0.22	23.6	0.3	0.06	0.18	--
	Treated TCLP	--	0.01	0.06	0.01	0.01	0.01	0.01	0.01	--
Chromium	Untreated TCLP	--	0.76	0.43	--	25.3	38.7	360	--	--
	Treated TCLP	--	0.45	0.09	--	0.44	0.89	1.41	--	--
Copper	Untreated TCLP	--	368	--	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP	--	0.27	--	0.29	0.31	0.22	0.45	0.35	0.50
Lead	Untreated TCLP	--	10.7	--	--	--	3.37	1.0	4.22	50.2
	Treated TCLP	--	0.39	--	--	--	0.39	0.41	0.40	0.29
Mercury	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Nickel	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP	0.05	0.03	0.27	0.02	0.04	0.06	0.11	0.04	0.02
Selenium	Untreated TCLP	--	--	--	--	--	--	--	--	--
	Treated TCLP	--	--	--	--	--	--	--	--	--
Silver	Untreated TCLP	--	0.14	--	0.16	--	0.12	--	0.31	--
	Treated TCLP	--	0.06	--	0.05	--	0.06	--	0.06	--
Zinc	Untreated TCLP	0.16	219	5.41	2,030	867	1,200	0.62	650	1.29
	Treated TCLP	0.03	0.01	.03	0.04	0.03	0.04	0.02	0.02	0.01

Binding agent: cement kiln dust.

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Reference: CWM Technical Note 87-117, Table 1 (CWM 1987).

6. SELECTION OF REGULATED CONSTITUENTS

As discussed in Section 1, the Agency has developed a list of hazardous constituents (see Table 1-1) from which the constituents to be regulated are selected. EPA may revise this list as additional data and information become available. The list is divided into the following categories: volatile organics, semivolatile organics, metals, inorganics other than metals, organochlorine pesticides, phenoxyacetic acid herbicides, organophosphorous insecticides, PCBs, and dioxins and furans.

This section describes the process used to select the constituents to be regulated. The process involves developing a list of potential regulated constituents and then eliminating those constituents that would not be treated by the chosen BDAT or that would be controlled by regulation of the remaining constituents.

6.1 Identification of BDAT List Constituents in the Untreated Waste

As discussed in Sections 2 and 4, the Agency has characterization data (see Table 2-4) as well as performance data from the treatment of K087 waste by rotary kiln incineration (see Tables 4-1, 4-2, and 4-3). These data, along with information on the waste generating process, have been used to determine which BDAT list constituents may be present in the waste and thus which ones are potential candidates for regulation in the nonwastewater and wastewater.

Table 6-1, at the end of this section, indicates, for the untreated waste, which constituents were analyzed, which constituents were detected, and which constituents the Agency believes could be present though not detected. For those constituents detected, concentrations are indicated.

Under the column "Believed to be present," constituents other than those detected in the untreated waste are marked with X or Y if EPA believes they are likely to be present in the untreated waste. For those constituents marked with X, an engineering analysis of the waste generating process indicates that they are likely to be present (e.g., the engineering analysis shows that a particular constituent is present in a major raw material). Those constituents marked with Y have been detected in the treated residual(s) and thus EPA believes they are present in the untreated waste. Constituents may not have been detected in the untreated waste for one of several reasons: (1) none of the untreated waste samples were analyzed for those constituents, (2) masking or interference by other constituents prevented detection, or (3) the constituent indeed was not present. (With regard to Reason (3), it is important to note that some wastes are defined as being generated from a process that may use variable raw materials composed of different constituents. Therefore, all potentially regulated constituents would not necessarily be present in any given sample.)

In samples collected during the K087 test burn, EPA analyzed for 192 of the 231 BDAT list constituents. EPA did not analyze for 20 organochlorine pesticides, 3 phenoxyacetic acid herbicides, 5 organophosphorous insecticides, 7 volatile organics, 3 semivolatile organics, or 1 metal; EPA believes that all of these compounds are unlikely to be present in the waste because there is no in-process source for these constituents. Of the analyzed constituents, 37 were detected. EPA found 19 BDAT organics,* 9 BDAT metals, and 3 BDAT inorganics other than metals (i.e., cyanide, sulfide, and fluoride) in the untreated waste. In the treated residuals, the Agency found 1 additional organic and 5 additional metals. (Tables D-1 through D-3 in Appendix D show the detection limits for the test burn performance data.) The other waste characterization data (as shown in Table 2-4) indicate that 5 more BDAT organics may be present in the untreated K087 waste. All 42 of these constituents are potential candidates for regulation.

6.2 Constituent Selection

EPA has chosen to regulate 10 constituents out of the 42 candidates for regulation in K087 waste. These constituents include 3 volatile organics, 6 semivolatile organics, and 1 metal, as shown in Table 6-2.

For the organics, EPA selected constituents that are present in the untreated waste at the greatest concentrations (as shown by the characterization data) and constituents that are believed to be more difficult to treat based on an analysis of characteristics affecting performance of rotary kiln incineration. Of the volatile organics, benzene, toluene, and xylenes are present in the untreated wastes at higher concentrations in comparison to methyl ethyl ketone. Benzene, toluene, and xylenes are also expected to be easier to treat based on the boiling points and theoretical bond energies. Therefore, these three compounds are being regulated.

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* The xylene isomers, 1,2-xylene, 1,3-xylene, and 1,4-xylene, are being considered as one constituent here because they were not analyzed separately.

For the semivolatile organics, the concentrations of naphthalene, phenanthrene, fluoranthene, and acenaphthalene were highest relative to the concentrations of the rest of the semivolatile constituents. These four compounds, along with indeno(1,2,3-cd)pyrene and chrysene, which have relatively high boiling points and/or theoretical bond energies, also are being regulated. (Table 6-3 shows the boiling points and calculated theoretical bond energies for the organic constituents.)

As discussed in Section 3.2.2, both the volatility of a constituent and its combustibility affect whether the constituent will undergo treatment in an incinerator or through another thermal destruction technology. The Agency believes that the boiling point of a pure constituent under ideal conditions will provide some indication of its volatility in waste undergoing incineration. The higher the boiling point of a component, in general, the more difficult that component is to treat. The Agency also believes that theoretical bond energies give an indication of combustibility. In general, the higher the bond energy for a constituent, the more difficult it is to combust that constituent.

In EPA's analysis of the boiling points of the semivolatiles in K087 waste, indeno(1,2,3-cd) pyrene, chrysene, dibenzo(ah)anthracene, and anthracene, rank as the most difficult to treat. In the analysis of theoretical bond energies, indeno(1,2,3-cd) pyrene, benzoperylene, and dibenzo(ah)anthracene rank as the most difficult to treat. By regulating indeno(1,2,3-cd) pyrene and chrysene along with the compounds that are present in the highest concentrations, EPA believes that treatment will occur for the remaining BDAT list organic constituents.

For the metals, EPA has chosen to regulate lead, which is present in the greatest concentration relative to the rest of the metals. As discussed in Section 4.2, BDAT for the organics in K087 waste generates both nonwastewater and wastewater residuals that may require treatment for metals. Analytical results from samples collected during the K087 test burn show that few metals in the scrubber water or in the ash were generated in quantities that could be treated by chemical precipitation and sludge filtration or by stabilization, respectively. In general, the Agency eliminates constituents from consideration as regulated constituents those constituents that cannot be significantly treated by the technologies designated as BDAT. In the case of K087 waste, however, metals are not excluded as potential regulated constituents because the untreated K087 waste contains metals, and it is probable that other K087 incinerator residuals will have treatable concentrations of these metals, as discussed below.

An incinerator is not specifically designed to treat metals. Accordingly, the concentration of metals found in the scrubber water and in the ash will depend on the specific design and operating parameters selected for volatilization and destruction of the organic constituents in the waste, including operating temperatures, residence times, and turbulence effects. For example, an incinerator that operates at a higher temperature would be expected to have higher metal concentrations in the scrubber water than would an incinerator that operates at a lower temperature. Also, metal residual concentrations will vary from one incinerator test to the next because the untreated wastes can have different concentrations of a particular metal constituent.

Table 6-1 Status of BDAT List Constituent Presence in Untreated K087 Waste

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile Organics		
222.	Acetone	ND	
1.	Acetonitrile	ND	
2.	Acrolein	ND	
3.	Acrylonitrile	ND	
4.	Benzene	6-410	
5.	Bromodichloromethane	ND	
6.	Bromomethane	ND	
223.	n-Butyl alcohol	NA	
7.	Carbon tetrachloride	ND	
8.	Carbon disulfide	ND	
9.	Chlorobenzene	ND	
10.	2-Chloro-1,3-butadiene	ND	
11.	Chlorodibromomethane	ND	
12.	Chloroethane	ND	
13.	2-Chloroethyl vinyl ether	ND	
14.	Chloroform	ND	
15.	Chloromethane	ND	
16.	3-Chloropropene	ND	
17.	1,2-Dibromo-3-chloropropane	ND	
18.	1,2-Dibromoethane	ND	
19.	Dibromomethane	ND	
20.	trans-1,4-Dichloro-2-butene	ND	
21.	Dichlorodifluoromethane	ND	
22.	1,1-Dichloroethane	ND	
23.	1,2-Dichloroethane	ND	
24.	1,1-Dichloroethylene	ND	
25.	trans-1,2-Dichloroethene	ND	
26.	1,2-Dichloropropane	ND	
27.	trans-1,3-Dichloropropene	ND	
28.	cis-1,3-Dichloropropene	ND	
29.	1,4-Dioxane	ND	
224.	2-Ethoxyethanol	NA	
225.	Ethyl acetate	NA	
226.	Ethyl benzene	ND	
30.	Ethyl cyanide	ND	
227.	Ethyl ether	NA	
31.	Ethyl methacrylate	ND	
214.	Ethylene oxide	ND	
32.	Iodomethane	ND	
33.	Isobutyl alcohol	ND	
228.	Methanol	NA	
34.	Methyl ethyl ketone	ND	Y

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Volatile Organics (continued)		
229.	Methyl isobutyl ketone	ND	
35.	Methyl methacrylate	ND	
37.	Methacrylonitrile	ND	
38.	Methylene chloride	ND	
230.	2-Nitropropane	NA	
39.	Pyridine	ND	
40.	1,1,1,2-Tetrachloroethane	ND	
41.	1,1,2,2-Tetrachloroethane	ND	
42.	Tetrachloroethene	ND	
43.	Toluene	17-260	
44.	Tribromomethane	ND	
45.	1,1,1-Trichloroethane	ND	
46.	1,1,2-Trichloroethane	ND	
47.	Trichloroethene	ND	
48.	Trichloromonofluoromethane	ND	
49.	1,2,3-Trichloropropane	ND	
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	
50.	Vinyl chloride	ND	
215.	1,2-Xylene		
216.	1,3-Xylene		
217.	1,4-Xylene	3-700[b]	
	Semivolatile Organics		
51.	Acenaphthalene	10,000-24,200	
52.	Acenaphthene	380-900	
53.	Acetophenone	ND	
54.	2-Acetylaminofluorene	ND	
55.	4-Aminobiphenyl	ND	
56.	Aniline	ND	
57.	Anthracene	6,700-14,200	
58.	Aramite	ND	
59.	Benz(a)anthracene	5,400-8,465	
218.	Benzal chloride	NA	
60.	Benzenethiol	ND	
61.	Deleted		
62.	Benzo(a)pyrene	3,800-8,450	
63.	Benzo(b)fluoranthene	1,900-8,650	
64.	Benzo(ghi)perylene	1,500-6,700	
65.	Benzo(k)fluoranthene	2,900-9,300	
66.	p-Benzoquinone	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile Organics (continued)		
67.	Bis(2-chloroethoxy)methane	ND	
68.	Bis(2-chloroethyl)ether	ND	
69.	Bis(2-chloroisopropyl)ether	ND	
70.	Bis(2-ethylhexyl)phthalate	ND	
71.	4-Bromophenyl phenyl ether	ND	
72.	Butyl benzyl phthalate	ND	
73.	2-sec-Butyl-4,6-dinitrophenol	ND	
74.	p-Chloroaniline	ND	
75.	Chlorobenzilate	ND	
76.	p-Chloro-m-cresol	ND	
77.	2-Chloronaphthalene	ND	
78.	2-Chlorophenol	ND	
79.	3-Chloropropionitrile	ND	
80.	Chrysene	4,480-7,950	
81.	ortho-Cresol	396-425	
82.	para-Cresol	1,200-5,450	
232.	Cyclohexanone	NA	
83.	Dibenz(a,h)anthracene	580-1,750	
84.	Dibenzo(a,e)pyrene	ND	
85.	Dibenzo(a,i)pyrene	ND	
86.	m-Dichlorobenzene	ND	
87.	o-Dichlorobenzene	ND	
88.	p-Dichlorobenzene	ND	
89.	3,3'-Dichlorobenzidine	ND	
90.	2,4-Dichlorophenol	ND	
91.	2,6-Dichlorophenol	ND	
92.	Diethyl phthalate	ND	
93.	3,3'-Dimethoxybenzidine	ND	
94.	p-Dimethylaminoazobenzene	ND	
95.	3,3'-Dimethylbenzidine	ND	
96.	2,4-Dimethylphenol	256-820	
97.	Dimethyl phthalate	ND	
98.	Di-n-butyl phthalate	ND	
99.	1,4-Dinitrobenzene	ND	
100.	4,6-Dinitro-o-cresol	ND	
101.	2,4-Dinitrophenol	ND	
102.	2,4-Dinitrotoluene	ND	
103.	2,6-Dinitrotoluene	ND	
104.	Di-n-octyl phthalate	ND	
105.	Di-n-propylnitrosamine	ND	
106.	Diphenylamine	ND	
219.	Diphenylnitrosamine	ND	

Table 6-1 (Continued)

BOAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile Organics (continued)		
107.	1,2-Diphenylhydrazine	ND	
108.	Fluoranthene	1,200-28,200	
109.	Fluorene	7,000-14,200	
110.	Hexachlorobenzene	ND	
111.	Hexachlorobutadiene	ND	
112.	Hexachlorocyclopentadiene	ND	
113.	Hexachloroethane	ND	
114.	Hexachlorophene	ND	
115.	Hexachloropropene	ND	
116.	Indeno(1,2,3-cd)pyrene	1,600-6,150	
117.	Isosafrole	ND	
118.	Methapyrilene	ND	
119.	3-Methylcholanthrene	ND	
120.	4,4'-Methylenebis (2-chloroaniline)	ND	
36.	Methyl methanesulfonate	ND	
121.	Naphthalene	36,000-95,000	
122.	1,4-Naphthoquinone	ND	
123.	1-Naphthylamine	ND	
124.	2-Naphthylamine	ND	
125.	p-Nitroaniline	ND	
126.	Nitrobenzene	ND	
127.	4-Nitrophenol	ND	
128.	N-Nitrosodi-n-butylamine	ND	
129.	N-Nitrosodiethylamine	ND	
130.	N-Nitrosodimethylamine	ND	
131.	N-Nitrosomethylethylamine	ND	
132.	N-Nitrosomorpholine	ND	
133.	N-Nitrosopiperidine	ND	
134.	N-Nitrosopyrrolidine	ND	
135.	5-Nitro-o-toluidine	ND	
136.	Pentachlorobenzene	ND	
137.	Pentachloroethane	ND	
138.	Pentachloronitrobenzene	ND	
139.	Pentachlorophenol	ND	
140.	Phenacetin	ND	
141.	Phenanthrene	15,000-43,200	
142.	Phenol	490-5,900	
220.	Phthalic anhydride	NA	
143.	2-Picoline	ND	
144.	Pronamide	ND	
145.	Pyrene	5,900-20,500	
146.	Resorcinol	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Semivolatile Organics (continued)		
147.	Safrole	ND	
148.	1,2,4,5-Tetrachlorobenzene	ND	
149.	2,3,4,6-Tetrachlorophenol	ND	
150.	1,2,4-Trichlorobenzene	ND	
151.	2,4,5-Trichlorophenol	ND	
152.	2,4,6-Trichlorophenol	ND	
153.	Tris(2,3-dibromopropyl) phosphate	ND	
	Metals		
154.	Antimony	ND	Y
155.	Arsenic	0.28-20	
156.	Barium	ND	Y
157.	Beryllium	ND	Y
158.	Cadmium	1.7-2.1	
159.	Chromium (total)	ND	Y
221.	Chromium (hexavalent)	NA	
160.	Copper	2.6-4.5	
161.	Lead	31-154	
162.	Mercury	2.9-4.2	
163.	Nickel	4.0-4.6	
164.	Selenium	1.2-1.6	
165.	Silver	ND	
166.	Thallium	2.1-2.7	
167.	Vanadium	ND	Y
168.	Zinc	50-66	
	Inorganics Other Than Metals		
169.	Cyanide	17.9-228	
170.	Fluoride	0.18-0.38	
171.	Sulfide	275-323	
	Organochlorine Pesticides		
172.	Aldrin	NA	
173.	alpha-BHC	NA	
174.	beta-BHC	NA	
175.	delta-BHC	NA	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Organochlorine Pesticides (continued)		
176.	gamma-BHC	NA	
177.	Chlordane	NA	
178.	DDD	NA	
179.	DDE	NA	
180.	DDT	NA	
181.	Dieldrin	NA	
182.	Endosulfan I	NA	
183.	Endosulfan II	NA	
184.	Endrin	NA	
185.	Endrin aldehyde	NA	
186.	Heptachlor	NA	
187.	Heptachlor epoxide	NA	
188.	Isodrin	NA	
189.	Kepone	NA	
190.	Methoxyclor	NA	
191.	Toxaphene	NA	
	Phenoxyacetic Acid Herbicides		
192.	2,4-Dichlorophenoxyacetic acid	NA	
193.	Silvex	NA	
194.	2,4,5-T	NA	
	Organophosphorous Insecticides		
195.	Disulfoton	NA	
196.	Famphur	NA	
197.	Methyl parathion	NA	
198.	Parathion	NA	
199.	Phorate	NA	
	PCBs		
200.	Aroclor 1016	ND	
201.	Aroclor 1221	ND	
202.	Aroclor 1232	ND	
203.	Aroclor 1242	ND	
204.	Aroclor 1248	ND	
205.	Aroclor 1254	ND	
206.	Aroclor 1260	ND	

Table 6-1 (Continued)

BDAT reference no.	Constituent	Detection status[a]	Believed to be present
	Dioxins and Furans		
207.	Hexachlorodibenzo-p-dioxins	ND	
208.	Hexachlorodibenzofurans	ND	
209.	Pentachlorodibenzo-p-dioxins	ND	
210.	Pentachlorodibenzofurans	ND	
211.	Tetrachlorodibenzo-p-dioxins	ND	
212.	Tetrachlorodibenzofurans	ND	
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	ND	

ND = Not detected.
NA = Not analyzed.
X = Believed to be present based on engineering analysis of waste generating process.
Y = Believed to be present based on detection in treated residuals.

[a] If detected, concentration is shown; units are mg/kg.

[b] Concentration for total xylenes.

Table 6-2 Regulated Constituents for K087 Waste

Constituent
BDAT Volatile Organics
Benzene
Toluene
Xylenes
BDAT Semivolatile Organics
Acenaphthalene
Chrysene
Fluoranthene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
BDAT Metals
Lead

Table 6-3 Characteristics of the BDAT Organic Compounds in K087 Waste That May Affect Performance in Rotary Kiln Incineration Systems

Constituent	Boiling point (°C)[a]	Calculated bond energy[b] (kcal/mol)
BDAT Volatile Organics		
Benzene	80.1	1320
Methyl ethyl ketone	79.6	1215
Toluene	110.8	1235
Xylenes (o-,m-,and p-)	138.4 - 144.4	1220
BDAT Semivolatile Organics		
Acenaphthalene	280	2400
Acenaphthene[a]	279	2540
Anthracene	340	2865
Benz(a)anthracene	435	3650
Benzo(b)fluoranthene	-	4000
Benzo(k)fluoranthene	480	4000
Benzo(ghi)perylene[a]	-	4350
Benzo(a)pyrene	311	4000
Chrysene	488	3650
ortho-Cresol[a]	191	1405
para-Cresol	202	1405
2,4-Dimethylphenol[a]	211.5	1390
Dibenzo(ah)anthracene[a]	524	4430
Fluoranthene	250	3190
Fluorene	293-295	2700
Indeno(1,2,3-cd)pyrene	536	4350
Naphthalene	217.9	2094
Phenanthrene	340	2880
Phenol	182	1421
Pyrene	393	3210

- = No information available.

[a] Sources for boiling point information are Verschueren 1983, Perry 1973, CRC 1986.

[b] Calculations are based on information in Sanderson 1971.

7. CALCULATION OF BDAT TREATMENT STANDARDS

This section details the calculation of treatment standards for the regulated constituents selected in Section 6. EPA is setting treatment standards for K087 waste based on performance data from (1) rotary kiln incineration of K087 waste, (2) chemical precipitation and sludge filtration of a metal-bearing wastewater sampled by EPA, and (3) stabilization of F006 waste.

For treatment of BDAT list organics, all five data sets for nonwastewater and six data sets for wastewater reflect treatment in a well-designed and well-operated rotary kiln incineration system, which is the determined BDAT. Furthermore, they are accompanied by sufficient QA/QC data. Thus, the data meet the requirements for setting treatment standards.

For treatment of BDAT list metals in K087 waste, the 11 data sets for wastewater from chemical precipitation, using lime, and sludge filtration reflect treatment in a well-designed and well-operated system, which is the technology selected as BDAT. Sufficient QA/QC information is also available. Thus, these data points meet the requirements for setting treatment standards.

Also, for treatment of BDAT list metals in K087 waste, the nine data sets (see Table 5-1) for nonwastewater from stabilization of F006 waste using a cement kiln dust binder reflect treatment in a well-designed, well-operated system, result from BDAT, and are accompanied by sufficient QA/QC data. Thus, they meet the requirements for setting treatment standards. Note that the Agency is using only five data points for lead, as explained in Section 5.2.2.

As discussed in Section 1, the calculation of a treatment standard for a constituent to be regulated involves (1) adjusting the data points for accuracy, (2) determining the mean (arithmetic average) and variability factor (see Appendix A) for the data points, and (3) multiplying the mean and the variability factor together to determine the treatment standard.

The procedure for adjusting the data points is discussed in detail in Section 1.2.6. The data from each of the demonstrated technologies are adjusted in Appendix B. The unadjusted and accuracy-corrected values for the regulated constituents are presented in Tables 7-1 through 7-4, along with the accuracy-correction factors, means of the accuracy-corrected values, variability factors, and treatment standards.

Table 7-1 Calculation of Nonwastewater Treatment Standards for the Regulated Constituents Treated by Rotary Kiln Incineration

Constituent	Unadjusted concentration (mg/kg) Sample Set # 1	2	3	4	5	Correction factor	Accuracy corrected concentration (mg/kg) Sample Set # 1	2	3	4	5	Mean (mg/kg)	Variability factor	Treatment standard (mg/kg)
BDAT Volatile Organics														
Benzene	<0.025	<0.025	<0.025	<0.025	<0.025	1/0.98	<0.026	<0.026	<0.026	<0.026	<0.026	0.0255	2.8	0.071
Toluene	0.150	0.085	<0.025	<0.025	0.190	1.00	0.150	0.085	<0.025	<0.025	0.190	0.095	6.85	0.65
Xylenes	<0.025	<0.025	<0.025	<0.025	<0.025	1.00	0.025	<0.025	<0.025	<0.025	<0.025	0.025	2.8	0.070
BDAT Semivolatile Organics														
Acenaphthalene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4
Chrysene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4
Fluoranthene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4
Indeno(1,2,3-cd)-pyrene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4
Naphthalene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4
Phenanthrene	<1.00	<1.00	<1.00	<1.00	<1.00	1/0.822	<1.217	<1.217	<1.217	<1.217	<1.217	1.217	2.8	3.4

Table 7-2 Calculation of the Proposed Wastewater Treatment Standards for the Regulated Organic Constituents Treated by Rotary Kiln Incineration

Constituent	Unadjusted concentration (mg/l) Sample Set #						Correction factor	Accuracy-corrected concentration (mg/l) Sample Set #						Mean (mg/l)	Variability factor	Treatment standard (mg/l)
	1	2	3	4	5	6		1	2	3	4	5	6			
BDAT Volatile Organics																
Benzene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1.00	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	2.8	0.014
Toluene	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	1.00	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	0.005	1.54	0.003
Xylenes	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1.00	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	2.8	0.014
BDAT Semivolatile Organics																
Acenaphthalene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028
Chrysene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028
Fluoranthene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028
Indeno(1,2,3-cd)-pyrene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028
Naphthalene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028
Phenanthrene	<0.010	0.010	0.010	0.010	0.010	0.010	1.00	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.010	2.8	0.028

Table 7-3 Calculation of Wastewater Treatment Standards for the Regulated Metal Constituents Treated by Chemical Precipitation and Sludge Filtration

Constituent	Correction factor	Concentration (mg/l) Sample Set # 1	2	3	4	5	6	7	8	9	10	11	Mean (mg/l)	Variability factor	Treatment standard (mg/l)
BDAT Metals															
Lead															
Unadjusted		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Accuracy-corrected	1/0.76	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	2.8	0.037

Table 7-4 Calculation of Nonwastewater Treatment Standards for the Regulated Metal Constituents Treated by Stabilization

Constituent	Correction factor	TCLP leachate concentration (mg/l) Sample Set # 1	2	3	4	5	6	7	8	9	Mean (mg/l)	Variability factor	Treatment standard (mg/l)
BDAT Metals													
Lead													
Unadjusted	1/0.929	-	0.36[a]	-	-	-	0.36[a]	0.38[a]	0.37[a]	0.27[a]	-	-	-
Accuracy-corrected		-	0.39	-	-	-	0.39	0.41	0.40	0.29	0.375	1.37	0.51

[a] Data point from mix ratio of 0.5. Correction factors are 1/0.929 for lead and 1/1.014 for zinc.

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9. REFERENCES

Ackerman, D.G., McGaughey, J.F., and Wagoner, D.E. 1983. *At sea incineration of PCB-containing wastes on board the M/T Vulcanus*. EPA 600/7-83-024. Washington, D.C.: U.S. Environmental Protection Agency.

Ajax Floor Products Corp. n.d. Product literature: technical data sheets, Hazardous Waste Disposal System. P.O. Box 161, Great Meadows, N.J. 07838.

ASTM. 1986. American Society for Testing and Materials. *Annual book of ASTM standards*. Philadelphia, Pa.: American Society for Testing and Materials.

Austin, G.T. 1984. *Shreve's chemical process industries*. 5th ed. New York: McGraw-Hill Book Co.

Bishop, P.L., Ransom, S.B., and Grass, D.L. 1983. Fixation mechanisms in solidification/stabilization of inorganic hazardous wastes. In *Proceedings of the 38th Industrial Waste Conference, 10-12 May 1983*, at Purdue University, West Lafayette, Indiana.

Bonner, T.A., et al. 1981. *Engineering handbook for hazardous waste incineration*. SW-889. NTIS PB81-248163. Prepared by Monsanto Research Corporation under Contract no. 68-03-3025 for U.S. Environmental Protection Agency.

Castaldini, C., et al. 1986. *Disposal of hazardous wastes in industrial boilers and furnaces*. Park Ridge, N.J.: Noyes Publications.

Cherry, K.F. 1982. *Plating waste treatment*. pp. 45-67. Ann Arbor, Mich.: Ann Arbor Science, Inc.

Conner, J.R. 1986. Fixation and solidification of wastes. *Chemical Engineering* Nov. 10, 1986.

CRC. 1986. *CRC handbook of chemistry and physics*. 6th ed. R.C. Weast, ed. Boca Raton, Fla.: CRC Press, Inc.

Cullinane, M.J., Jr., Jones, L.W., and Malone, P.G. 1986. *Handbook for stabilization/solidification of hazardous waste*. U.S. Army Engineer Waterways Experiment Station. EPA report no. 540/2-86/001. Cincinnati, Ohio: U.S. Environmental Protection Agency.

Cushnie, G.C., Jr. 1985. *Electroplating wastewater pollution control technology*. pp. 48-62. 84-90. Park Ridge, N.J.: Noyes Publications.

Cushnie, G.C., Jr. 1984. Removal of metals from wastewater neutralization and precipitation. pp. 55-97. Park Ridge, N.J.: Noyes Publications.

CWM. 1987. Chemical Waste Management. Technical note 87-117, Stabilization treatment of selected metal containing wastes. September 22, 1987. Chemical Waste Management, 150 West 137th Street, Riverdale, Ill.

Electric Power Research Institute. 1980. FGD sludge disposal manual, 2nd ed. Prepared by Michael Baker Jr., Inc. EPRI CS-1515 Project 1685-I. Palo Alto, Calif.: Electric Power Research Institute.

Environ. 1985. Characterization of waste streams listed in 40 CFR Section 261 waste profiles. Vol. 2. Prepared for Waste Identification Branch, Characterization and Assessment Division. Washington, D.C.: U.S. Environmental Protection Agency.

Gurnham, C.F. 1955. Principles of industrial waste treatment. pp. 224-234. New York: John Wiley and Sons.

Halverson, F., and Payer, H.P. 1980. Flocculating agents. In Encyclopedia of chemical technology, 3rd ed., pp. 489-516, New York: John Wiley and Sons.

Mishuck, E., Taylor, D.R., Telles, R., and Lubowitz, H. 1984. Encapsulation/fixation (E/F) mechanisms. Report no. DRXTH-TE-CR-84298. Prepared by S-Cubed under Contract no. DAAK11-81-C-0164. AD-A146177.

Mitre Corp. 1983. Guidance manual for hazardous waste incinerator permits. NTIS PB84-100577.

Novak, R.G., Troxler, W.L., and Dehnke, T.H. 1984. Recovering energy from hazardous waste incineration. Chemical Engineering Progress 91:146.

Oppelt, E.T. 1987. Incineration of hazardous waste. JAPCA 37(5).

Perch, M. 1979. Coal conversion processes (carbonization). In Kirk-Othmer encyclopedia of chemical technology. 3rd ed. Vol. 6. New York: John Wiley and Sons.

Perry, R.H., ed. 1973. Chemical engineer's handbook. 5th ed. New York: McGraw-Hill Book Co.

Pojasek, R.B. 1979. Solid-waste disposal: solidification. Chemical Engineering 86(17):141-145.

Sanderson. 1971. Chemical bonds and bond energy. Vol. 21. In Physical chemistry. New York: Academic Press.

Santoleri, J.J. 1983. Energy recovery--a by-product of hazardous waste incineration systems. In Proceedings of the 15th Mid-Atlantic Industrial Waste Conference on Toxic and Hazardous Waste.

USDOE. 1988. U.S. Department of Energy. Computer printout: EIA3 (Energy Information Administration) mailing list, EIA5-coke plant survey respondents. Retrieved Jan. 14, 1988. Washington, D.C.: U.S. Department of Energy.

USEPA. 1980a. U.S. Environmental Protection Agency, Office of Solid Waste. RCRA listing background document for K087. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1980b. U.S. Environmental Protection Agency. U.S. Army Engineer Waterways Experiment Station. Guide to the disposal of chemically stabilized and solidified waste. Prepared for MERL/ORD under Interagency Agreement No. EPA-IAG-D4-0569. P881-181505. Cincinnati, Ohio.

USEPA. 1983. U.S. Environmental Protection Agency. Treatability manual. Vol. III. Technology for control/removal of pollutants. EPA-600/2-82-001c. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986a. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Test methods for evaluating solid waste. SW-846, 3rd ed. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986b. U.S. Environmental Protection Agency. Hazardous waste management systems; land disposal restrictions; final rule: Appendix I to Part 268 - Toxicity Characteristic Leaching Procedure (TCLP). 51 FR 40643-54, November 7, 1986.

USEPA. 1986c. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for Envirite Corporation, York, Pennsylvania. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986d. U.S. Environmental Protection Agency. Best demonstrated available technology (BDAT) background document for F001-F005 spent solvents. Vol. 1. EPA/530-SW-86-056. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1987a. U.S. Environmental Protection Agency, Office of Solid Waste. Generic quality assurance project plan for land disposal restrictions program ("BDAT"). EPA/530-SW-87-011. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1987b. U.S. Environmental Protection Agency, Office of Solid Waste. Burning of hazardous waste in boilers and industrial furnaces; proposed rule. 52 FR 17012, May 6, 1987.

USEPA. 1988a. U.S. Environmental Protection Agency. Onsite engineering report of treatment technology performance and operation for K087 waste at the Combustion Research Facility, Jefferson, Arkansas. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988b. U.S. Environmental Protection Agency. Onsite engineering report of treatment technology and performance for K061 waste at Horsehead Resource Development Co., Inc. Palmerton, Pennsylvania. Washington, D.C.: U.S. Environmental Protection Agency.

Versar Inc. 1984. Estimating PMN incineration results. Contract no. 68-01-6271. Draft report for Office of Toxic Substances. Washington, D.C.: U.S. Environmental Protection Agency.

Verschueren, Karel. 1983. Handbook of environmental data on organic chemicals. 2nd ed. New York: Van Nostrand Reinhold Company, Inc.

Vogel, G., et al. 1986. Incineration and cement kiln capacity for hazardous waste treatment. In Proceedings of the 12th Annual Research Symposium on Incineration and Treatment of Hazardous Wastes, April 1986, Cincinnati, Ohio.

APPENDIX A

STATISTICAL METHODS

A.1 F Value Determination for ANOVA Test

As noted in Section 1.2, EPA is using the statistical method known as analysis of variance (ANOVA) to determine the level of performance that represents "best" treatment where more than one technology is demonstrated. This method provides a measure of the differences between data sets.

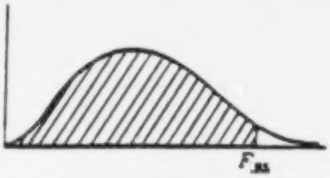
If the Agency found that the levels of performance for one or more technologies are not statistically different (i.e., the data sets are homogeneous), EPA would average the long-term performance values achieved by each technology and then multiply this value by the largest variability factor associated with any of the acceptable technologies. If EPA found that one technology performs significantly better (i.e., the data sets are not homogeneous), the "best" technology would be the technology that achieves the best level of performance, i.e., the technology with the lowest mean value.

To determine whether any or all of the treatment performance data sets are homogeneous using the analysis of variance method, it is necessary to compare a calculated "F value" to what is known as a "critical value." (See Table A-1.) These critical values are available in most statistics texts (see, for example, Statistical Concepts and Methods by Bhattacharyya and Johnson, 1977, John Wiley Publications, New York).

Table A-1

95th PERCENTILE VALUES FOR THE F DISTRIBUTION

n_1 = degrees of freedom for numerator
n_2 = degrees of freedom for denominator
(shaded area = .95)



n_2 \ n_1	1	2	3	4	5	6	8	12	16	20	30	40	50	100	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	238.9	243.9	246.3	248.0	250.1	251.1	252.2	253.0	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.37	19.41	19.43	19.45	19.46	19.46	19.47	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.85	8.74	8.69	8.66	8.62	8.60	8.58	8.56	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.04	5.91	5.84	5.80	5.75	5.71	5.70	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.82	4.68	4.60	4.56	4.50	4.46	4.44	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.15	4.00	3.92	3.87	3.81	3.77	3.75	3.71	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.73	3.57	3.49	3.44	3.38	3.34	3.32	3.28	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.44	3.28	3.20	3.15	3.08	3.05	3.03	2.98	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.23	3.07	2.98	2.93	2.86	2.82	2.80	2.76	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.07	2.91	2.82	2.77	2.70	2.67	2.64	2.59	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.95	2.79	2.70	2.65	2.57	2.53	2.50	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.85	2.69	2.60	2.54	2.46	2.42	2.40	2.35	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.77	2.60	2.51	2.46	2.38	2.34	2.32	2.26	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.70	2.53	2.44	2.39	2.31	2.27	2.24	2.19	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.64	2.48	2.39	2.33	2.25	2.21	2.18	2.12	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.59	2.42	2.33	2.28	2.20	2.16	2.13	2.07	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.55	2.38	2.29	2.23	2.15	2.11	2.08	2.02	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.51	2.34	2.25	2.19	2.11	2.07	2.04	1.98	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.48	2.31	2.21	2.15	2.07	2.02	2.00	1.94	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.45	2.28	2.18	2.12	2.04	1.99	1.96	1.90	1.84
22	4.30	3.44	3.05	2.82	2.66	2.55	2.40	2.23	2.13	2.07	1.98	1.93	1.91	1.84	1.78
24	4.26	3.40	3.01	2.78	2.62	2.51	2.36	2.18	2.09	2.03	1.94	1.89	1.86	1.80	1.73
26	4.23	3.37	2.98	2.74	2.59	2.47	2.32	2.15	2.05	1.99	1.90	1.85	1.82	1.76	1.69
28	4.20	3.34	2.95	2.71	2.56	2.45	2.29	2.12	2.02	1.96	1.87	1.81	1.78	1.72	1.65
30	4.17	3.32	2.92	2.69	2.53	2.42	2.27	2.09	1.99	1.93	1.84	1.79	1.76	1.69	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.18	2.00	1.90	1.84	1.74	1.69	1.66	1.59	1.51
50	4.03	3.18	2.79	2.56	2.40	2.29	2.13	1.95	1.85	1.78	1.69	1.63	1.60	1.52	1.44
60	4.00	3.15	2.76	2.53	2.37	2.25	2.10	1.92	1.81	1.75	1.65	1.59	1.56	1.48	1.39
70	3.98	3.13	2.74	2.50	2.35	2.23	2.07	1.89	1.79	1.72	1.62	1.56	1.53	1.45	1.35
80	3.96	3.11	2.72	2.48	2.33	2.21	2.05	1.88	1.77	1.70	1.60	1.54	1.51	1.42	1.32
100	3.94	3.09	2.70	2.46	2.30	2.19	2.03	1.85	1.75	1.68	1.57	1.51	1.48	1.39	1.28
150	3.91	3.06	2.67	2.43	2.27	2.16	2.00	1.82	1.71	1.64	1.54	1.47	1.44	1.34	1.22
200	3.89	3.04	2.65	2.41	2.26	2.14	1.98	1.80	1.69	1.62	1.52	1.45	1.42	1.32	1.19
400	3.86	3.02	2.62	2.39	2.23	2.12	1.96	1.78	1.67	1.60	1.49	1.42	1.38	1.28	1.13
∞	3.84	2.99	2.60	2.37	2.21	2.09	1.94	1.75	1.64	1.57	1.46	1.40	1.32	1.24	1.00

Where the F value is less than the critical value, all treatment data sets are homogeneous. If the F value exceeds the critical value, it is necessary to perform a "pair wise F" test to determine if any of the sets are homogeneous. The "pair wise F" test must be done for all of the various combinations of data sets using the same method and equation as the general F test.

The F value is calculated as follows:

(i) All data are natural logtransformed.

(ii) The sum of the data points for each data set is computed (T_i).

(iii) The statistical parameter known as the sum of the squares between data sets (SSB) is computed:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

where:

k = number of treatment technologies
n_i = number of data points for technology i
N = number of data points for all technologies
T_i = sum of natural logtransformed data points for each technology.

(iv) The sum of the squares within data sets (SSW) is computed:

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

where:

$x_{i,j}$ = the natural logtransformed observations (j) for treatment technology (i).

(v) The degrees of freedom corresponding to SSB and SSW are calculated. For SSB, the degree of freedom is given by k-1. For SSW, the degree of freedom is given by N-k.

(vi) Using the above parameters, the F value is calculated as follows:

$$F = \frac{MSB}{MSW}$$

where:

$MSB = SSB/(k-1)$ and
$MSW = SSW/(N-k)$.

A computational table summarizing the above parameters is shown below.

Computational Table for the F Value

Source	Degrees of freedom	Sum of squares	Mean square	F value
Between	k-1	SSB	MSB = SSB/k-1	MSB/MSW
Within	N-k	SSW	MSW = SSW/N-k	

Below are three examples of the ANOVA calculation. The first two represent treatment by different technologies that achieve statistically similar treatment; the last example represents a case in which one technology achieves significantly better treatment than the other technology.

Example 1
Methylene Chloride

Steam stripping				Biological treatment			
Influent (µg/l)	Effluent (µg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent (µg/l)	Effluent (µg/l)	ln(effluent)	$[\ln(\text{effluent})]^2$
1550.00	10.00	2.30	5.29	1960.00	10.00	2.30	5.29
1290.00	10.00	2.30	5.29	2568.00	10.00	2.30	5.29
1640.00	10.00	2.30	5.29	1817.00	10.00	2.30	5.29
5100.00	12.00	2.48	6.15	1640.00	26.00	3.26	10.63
1450.00	10.00	2.30	5.29	3907.00	10.00	2.30	5.29
4600.00	10.00	2.30	5.29				
1760.00	10.00	2.30	5.29				
2400.00	10.00	2.30	5.29				
4800.00	10.00	2.30	5.29				
12100.00	10.00	2.30	5.29				
Sum:							
-	-	23.18	53.76	-	-	12.46	31.79
Sample Size:							
10	10	10	-	5	5	5	-
Mean:							
3669	10.2	2.32	-	2378	13.2	2.49	-
Standard Deviation:							
3328.67	.63	.06	-	923.04	7.15	.43	-
Variability Factor:							
	1.15	-	-	-	2.48	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

Example 1 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of natural logtransformed data points for all technologies

T_i = sum of logtransformed data points for each technology

X_{ij} = the nat. logtransformed observations (j) for treatment technology (i)

$n_1 = 10$, $n_2 = 5$, $N = 15$, $k = 2$, $T_1 = 23.18$, $T_2 = 12.46$, $T = 35.64$, $T^2 = 1270.21$

$T_1^2 = 537.31$ $T_2^2 = 155.25$

$$SSB = \left(\frac{537.31}{10} + \frac{155.25}{5}\right) - \frac{1270.21}{15} = 0.10$$

$$SSW = (53.76 + 31.79) - \left(\frac{537.31}{10} + \frac{155.25}{5}\right) = 0.77$$

$MSB = 0.10/1 = 0.10$

$MSW = 0.77/13 = 0.06$

$$F = \frac{0.10}{0.06} = 1.67$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.10	0.10	1.67
Within(W)	13	0.77	0.06	

The critical value of the F test at the 0.05 significance level is 4.67. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 2
Trichloroethylene

Steam stripping				Biological treatment			
Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$
1650.00	10.00	2.30	5.29	200.00	10.00	2.30	5.29
5200.00	10.00	2.30	5.29	224.00	10.00	2.30	5.29
5000.00	10.00	2.30	5.29	134.00	10.00	2.30	5.29
1720.00	10.00	2.30	5.29	150.00	10.00	2.30	5.29
1560.00	10.00	2.30	5.29	484.00	16.25	2.79	7.78
10300.00	10.00	2.30	5.29	163.00	10.00	2.30	5.29
210.00	10.00	2.30	5.29	182.00	10.00	2.30	5.29
1600.00	27.00	3.30	10.89				
204.00	85.00	4.44	19.71				
160.00	10.00	2.30	5.29				
Sum:							
-	-	26.14	72.92	-	-	16.59	39.52
Sample Size:							
10	10	10	-	7	7	7	-
Mean:							
2760	19.2	2.61	-	220	10.89	2.37	-
Standard Deviation:							
3209.6	23.7	.71	-	120.5	2.36	.19	-
Variability Factor:							
-	3.70	-	-	-	1.53	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$MSB = SSB/(k-1)$

$MSW = SSW/(N-k)$

Example 2 (Continued)

$F = MSB/MSW$

where:

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 10$, $N_2 = 7$, $N = 17$, $k = 2$, $T_1 = 26.14$, $T_2 = 16.59$, $T = 42.73$, $T^2 = 1825.85$, $T_1^2 = 683.30$,

$T_2^2 = 275.23$

$$SSB = \left[\frac{683.30}{10} + \frac{275.23}{7}\right] - \frac{1825.85}{17} = 0.25$$

$$SSW = (72.92 + 39.52) - \left(\frac{683.30}{10} + \frac{275.23}{7}\right) = 4.79$$

$MSB = 0.25/1 = 0.25$

$MSW = 4.79/15 = 0.32$

$$F = \frac{0.25}{0.32} = 0.78$$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	0.25	0.25	0.78
Within(W)	15	4.79	0.32	

The critical value of the F test at the 0.05 significance level is 4.54. Since the F value is less than the critical value, the means are not significantly different (i.e., they are homogeneous).

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

Example 3
Chlorobenzene

Activated sludge followed by carbon adsorption				Biological treatment			
Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$[\ln(\text{effluent})]^2$	Influent ($\mu g/l$)	Effluent ($\mu g/l$)	ln(effluent)	$\ln[(\text{effluent})]^2$
7200.00	80.00	4.38	19.18	9206.00	1083.00	6.99	48.86
6500.00	70.00	4.25	18.06	16646.00	709.50	6.56	43.03
6075.00	35.00	3.56	12.67	49775.00	460.00	6.13	37.58
3040.00	10.00	2.30	5.29	14731.00	142.00	4.96	24.60
				3159.00	603.00	6.40	40.96
				6756.00	153.00	5.03	25.30
				3040.00	17.00	2.83	8.01
Sum:							
-	-	14.49	55.20	-	-	38.90	228.34
Sample Size:							
4	4	4	-	7	7	7	-
Mean:							
5703	49	3.62	-	14759	452.5	5.56	-
Standard Deviation:							
1835.4	32.24	.95		16311.86	379.04	1.42	-
Variability Factor:							
-	7.00	-	-	-	15.79	-	-

ANOVA Calculations:

$$SSB = \left[\sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right) \right] - \left[\frac{\left(\sum_{i=1}^{k} T_i \right)^2}{N} \right]$$

$$SSW = \left[\sum_{i=1}^{k} \sum_{j=1}^{n_i} x^2{}_{i,j} \right] - \sum_{i=1}^{k} \left(\frac{T_i^2}{n_i} \right)$$

$$MSB = SSB/(k-1)$$

$$MSW = SSW/(N-k)$$

$$F = MSB/MSW$$

Example 3 (Continued)

where,

k = number of treatment technologies

n_i = number of data points for technology i

N = number of data points for all technologies

T_i = sum of natural logtransformed data points for each technology

X_{ij} = the natural logtransformed observations (j) for treatment technology (i)

$N_1 = 4,\ N_2 = 7,\ N = 11,\ k = 2,\ T_1 = 14.49,\ T_2 = 38.90,\ T = 53.39,\ T^2 = 2850.49,\ T_1^2 = 209.96$

$T_2^2 = 1513.21$

$$SSB = \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] - \frac{2850.49}{11} = 9.52$$

$$SSW = (55.20 + 228.34) - \left[\frac{209.96}{4} + \frac{1513.21}{7}\right] = 14.88$$

$MSB = 9.52/1 = 9.52$

$MSW = 14.88/9 = 1.65$

$F = 9.52/1.65 = 5.77$

ANOVA Table

Source	Degrees of freedom	SS	MS	F value
Between(B)	1	9.53	9.53	5.77
Within(W)	9	14.89	1.65	

The critical value of the F test at the 0.05 significance level is 5.12. Since the F value is larger than the critical value, the means are significantly different (i.e., they are heterogeneous). Activated sludge followed by carbon adsorption is "best" in this example because the mean of the long-term performance value, i.e., the effluent concentration, is lower.

Note: All calculations were rounded to two decimal places. Results may differ depending upon the number of decimal places used in each step of the calculations.

A.2 Variability Factor

$$VF = \frac{C_{99}}{\text{Mean}}$$

where:

VF = estimate of daily maximum variability factor determined from a sample population of daily data;

C_{99} = estimate of performance values for which 99 percent of the daily observations will be below. C_{99} is calculated using the following equation: $C_{99} = \text{Exp}(y + 2.33\ Sy)$ where y and Sy are the mean and standard deviation, respectively, of the logtransformed data; and

Mean = average of the individual performance values.

EPA is establishing this figure as an instantaneous maximum because the Agency believes that on a day-to-day basis the waste should meet the applicable treatment standards. In addition, establishing this requirement makes it easier to check compliance on a single day. The 99th percentile is appropriate because it accounts for almost all process variability.

In several cases, all the results from analysis of the residuals from BDAT treatment are found at concentrations less than the detection limit. In such cases, all the actual concentration values are considered unknown and, hence, cannot be used to estimate the variability factor of the analytical results. Below is a description of EPA's approach for calculating the variability factor for such cases with all concentrations below the detection limit.

It has been postulated as a general rule that a lognormal distribution adequately describes the variation among concentrations. Agency data show that the treatment residual concentrations are distributed approximately lognormally. Therefore, the lognormal model has been used routinely in the EPA development of numerous regulations in the Effluent Guidelines program and is being used in the BDAT program. The variability factor (VF) was defined as the ratio of the 99th percentile (C_{99}) of the lognormal distribution to its arithmetic mean (Mean), as follows:

$$VF = \frac{C_{99}}{Mean}. \qquad (1)$$

The relationship between the parameters of the lognormal distribution and the parameters of the normal distribution created by taking the natural logarithms of the lognormally distributed concentrations can be found in most mathematical statistics texts (see, for example, Distribution in Statistics-Volume 1 by Johnson and Kotz, 1970). The mean of the lognormal distribution can be expressed in terms of the mean (μ) and standard deviation (σ) of the normal distribution as follows:

$$C_{99} = \mathrm{Exp}\ (\mu + 2.33\sigma) \qquad (2)$$

$$Mean = \mathrm{Exp}\ (\mu + 0.5\sigma^2). \qquad (3)$$

By substituting (2) and (3) in (1), the variability factor can then be expressed in terms of σ as follows:

$$VF = \mathrm{Exp}\ (2.33\ \sigma - 0.5\sigma^2). \qquad (4)$$

For residuals with concentrations that are not all below the detection limit, the 99th percentile and the mean can be estimated from the actual analytical data and, accordingly, the variability factor (VF) can be estimated using equation (1). For residuals with concentrations that are below the detection limit, the above equations can be used in conjunction with the following assumptions to develop a variability factor.

- Assumption 1: The actual concentrations follow a lognormal distribution. The upper limit (UL) is equal to the detection limit. The lower limit (LL) is assumed to be equal to one-tenth of the detection limit. This assumption is based on the fact that data from well-designed and well-operated treatment systems generally fall within one order of magnitude.

- Assumption 2: The natural logarithms of the concentrations have a normal distribution with an upper limit equal to ln (UL) and a lower limit equal to ln (LL).

- Assumption 3: The standard deviation (σ) of the normal distribution is approximated by:

$$\sigma = [\ln(UL) - \ln(LL)] / [(2)(2.33)]$$
$$= [\ln(UL/LL)] / 4.66. \qquad (5)$$

(Note that when $LL = (0.1)(UL)$ as in Assumption 1, then $\sigma = (\ln 10) / 4.66 = 0.494$.)

Substitution of the σ value from equation (5) into equation (4) yields the variability factor, VF, as shown:

$$VF = 2.8. \qquad (6)$$

APPENDIX B

ANALYTICAL QA/QC

This appendix presents quality assurance/quality control (QA/QC) information for the available performance data presented in Section 4 and identifies the methods and procedures used for analyzing the constituents to be regulated. The QA/QC information includes matrix spike recovery data that are used for adjusting the analytical results for accuracy. The adjusted analytical results (referred to as accuracy-corrected concentrations), in general, are used for comparing the performance of one technology to that of another and for calculating treatment standards for those constituents to be regulated.

B.1 Accuracy Correction

The accuracy-corrected concentration for a constituent in a matrix is the analytical result multiplied by the correction factor (the reciprocol of the recovery fraction;* i.e., the correction factor is 100 divided by the percent recovery). For example, if Compound A is measured at 2.55 mg/l and the percent recovery is 85 percent, the accuracy-corrected concentration is 3.00 mg/l.

The recovery fraction is the ratio of (1) measured amount of constituent in a spiked aliquot minus the measured amount of constituent in the original unspiked aliquot to (2) the known amount of constituent added to spike the original aliquot. (Refer to the Generic Quality Assurance Project Plan for Land Disposal Restriction Program ("BDAT").)

2.55 mg/l	x	1/0.85	=	3.00 mg/l
(analytical result)		(correction factor)		(accuracy-corrected concentration)

The appropriate recovery values are selected according to the procedures specified in Section 1.2.6(3).

B.1.1 BDAT List Organics

Table B-1 presents matrix spike recovery data for the kiln ash residuals from rotary kiln incineration of K087 waste. Table B-2 presents the selected correction factors and the accuracy-corrected concentrations for the constituents listed in Table 4-2.

Table B-3 shows matrix spike recovery data for the scrubber water residuals from rotary kiln incineration of K087 waste. Table B-4 presents the selected correction factors and the accuracy-corrected concentrations for the constituents listed in Table 4-3.

B.1.2 BDAT List Metals

Table B-5 presents the selected correction factors and accuracy-corrected concentrations for the data from chemical precipitation and sludge filtration of BDAT list metals in wastewater (see Table 4-4). Matrix spike recovery data did not accompany these performance data. The correction factors are instead derived from matrix spike recovery data on metals in a similar wastewater matrix (see Table B-6).

Table B-7 presents matrix spike recovery data for metals in the TCLP extracts from stabilization of F006 waste. Table B-8 presents the selected correction factors and the accuracy-corrected concentrations for the metals listed in Table 4-5.

B.2 Methods and Procedures Employed to Generate the Data Used in Calculating Treatment Standards

Table B-9 lists the methods used for analyzing the constituents to be regulated in K087 waste. Most of these methods are specified in SW-846 (USEPA 1986a). For some analyses, SW-846 methods allow alternatives or equivalent procedures and/or equipment to be used. Tables B-10 and B-11 indicate the alternatives or equivalents employed in generating the data for the K087 treatment standards. The EPA Characterization and Assessment Division approved other alternatives to the SW-846 methods, and these are specified in Table B-12. Deviations are shown in Table B-13. The Agency plans to use these methods and procedures to enforce the treatment standards for K087 waste.

Table B-1 Matrix Spike Recovery Data for Kiln Ash Residuals from Rotary Kiln Incineration of K087 Waste

Constituent	Sample percent recovery	Duplicate percent recovery
Volatile Organics		
1,1-Dichloroethane	114	114
Trichloroethene	114	114
Chlorobenzene	106	106
Toluene	106	104
Benzene	100	98
(Average of volatiles)	(108)	(107.2)
Semivolatile Organics (acid-extractable)		
Pentachlorophenol	7[a]	11[a]
Phenol	77	80
2-Chlorophenol	78	83
4-Chloro-3-methylphenol	92	87
4-Nitrophenol	37	35
(Average of acid extractables)	(71)[a]	(71.25)[a]
Semivolatile Organics (base/neutral-extractable)		
1,2,4-Trichlorobenzene	84	89
Acenaphthene	93	91
2,4-Dinitrotoluene	121	109
Pyrene	34	39
N-Nitroso-di-n-propylamine	82	84
1,4-Dichlorobenzene	79	89
(Average of base/neutral extractables)	(82.17)	(83.5)
Metals (total concentration analysis)		
Antimony	23	22
Arsenic	44	48
Barium	78	76
Beryllium	78	78
Cadmium	76	88
Chromium	76	83
Copper	73	77
Lead	104	82
Mercury	120	100
Nickel	78	98
Selenium	92	92
Silver	72	72
Thallium	48	76
Vanadium	80	80
Zinc	78	80

Table B-1 (Continued)

Constituent	Sample percent recovery	Duplicate percent recovery
Metals (TCLP leachate concentration analysis)		
Antimony	44	42
Arsenic	98	104
Barium	67	85
Beryllium	78	90
Cadmium	96	96
Chromium	75	83
Copper	68	85
Lead	76	97
Mercury	100	96
Nickel	68	80
Selenium	96	100
Silver	88	84
Thallium	76	54
Vanadium	75	86
Zinc	71	86
Inorganics Other Than Metals		
Cyanide	96	58

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[a] Spike recovery values of 20 percent or less are not used in the development of treatment standards. Thus, the averages of the acid-extractable compounds do not reflect the recoveries of pentachlorophenol.

Reference: USEPA 1988a.

Table B-2 Accuracy-Corrected Analytical Results for Kiln Ash Generated by Rotary Kiln Incineration of K087 Waste

Constituent/parameter (units)	Correction factor	Accuracy-corrected concentration Sample Set # 1	2	3	4	5
BDAT Volatile Organics (mg/kg)						
Benzene	1/0.98	<0.026	<0.026	<0.026	<0.026	<0.026
Methyl ethyl ketone	1/1.00	<0.025	<0.025	<0.025	<0.025	<0.025
Toluene	1/1.00	0.150	0.085	<0.025	<0.025	0.190
Xylenes	1/1.00	<0.025	<0.025	<0.025	<0.025	<0.025
BDAT Semivolatile Organics (mg/kg)						
Acenaphthalene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Anthracene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Benz(a)anthracene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Benzo(b)fluoranthene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Benzo(k)fluoranthene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Benzo(a)pyrene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Chrysene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
para-Cresol	1/0.69	<1.4	<1.4	<1.4	<1.4	<1.4
Fluoranthene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Fluorene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Indeno(1,2,3-cd)pyrene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Naphthalene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Phenol	1/0.77	<1.3	<1.3	<1.3	<1.3	<1.3
Phenanthrene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Pyrene	1/0.34	<2.9	<2.9	<2.9	<2.9	<2.9
BDAT Metals (mg/kg)						
Antimony	1/0.22	<14.6	<9.1	<9.1	<9.1	<14.6
Arsenic	1/0.44	22	25	15	27	12
Barium	1/0.76	417	74	70	54	83
Beryllium	1/0.78	0.77	<0.6	<0.6	<0.6	0.46
Cadmium	1/0.76	<0.53	<1.3	<1.3	<1.3	<0.53
Chromium	1/0.76	45	6.8	2.9	2.8	10
Copper	1/0.73	1023	60	59	68	129
Lead	1/0.72	54	10	10.1	7.2	8.8
Mercury	1/1.00	<0.10	2.8	2.9	3.3	<0.1
Nickel	1/0.78	12	<5.1	<5.1	<5.1	5.8
Selenium	1/0.92	1.5	1.7	<0.54	6.4	<0.54
Silver	1/0.72	<0.83	<6.9	<6.9	<6.9	<8.3
Thallium	1/0.48	<2.1	<2.1	<2.1	<2.1	<2.1
Vanadium	1/0.80	21	12	8.2	10.1	12
Zinc	1/0.78	64	17	17	15	27

Table B-2 (Continued)

Constituent/parameter (units)	Correction factor	Accuracy-corrected concentration				
		Sample Set #				
		1	2	3	4	5
BDAT TCLP: Metals (mg/l)						
Antimony	1/0.42	1.019[a]	<0.047	<0.047	<0.047	<0.076
Arsenic	1/0.98	0.098	0.034	0.025	0.019	0.043
Barium	1/0.67	0.909	0.513	0.816	0.956	0.815
Beryllium	1/0.78	0.004	<0.006	<0.006	<0.006	0.003
Cadmium	1/0.96	<0.004	<0.010	<0.010	<0.010	<0.004
Chromium	1/0.75	0.082	<0.027	<0.027	<0.027	0.012
Copper	1/0.68	<0.009	0.076	1.632	0.509	0.731
Lead	1/0.76	0.038	0.053	0.070	0.026	0.139
Mercury	1/0.96	<0.0002	<0.0003	<0.0003	<0.0003	<0.0002
Nickel	1/0.68	0.136	<0.058	<0.059	<0.058	0.024
Selenium	1/0.96	<0.052	<0.007	<0.005	<0.005	<0.005
Silver	1/0.84	<0.007	<0.060	<0.060	<0.060	<0.007
Thallium	1/0.54	<0.018	<0.018	<0.018	<0.018	<0.926
Vanadium	1/0.75	<0.040	<0.066	<0.067	<0.067	0.011
Zinc	1/0.71	0.238	0.285	0.307	0.406	0.361
BDAT Inorganics Other Than Metals (mg/kg)						
Cyanide	1/0.58	1.28	<0.58	<0.58	<0.58	<0.58
Fluoride	-[b]	<1.0	-	-	-	<0.25
Sulfide	-[b]	35.5	36.3	144	116	11.0
Other Volatile Organics (mg/kg)						
Styrene	1/1.00	<0.025	<0.025	<0.025	<0.025	<0.025
Other Semivolatile Organics (mg/kg)						
Dibenzofuran	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
2-Methylnaphthalene	1/0.82	<1.2	<1.2	<1.2	<1.2	<1.2
Other Parameters (mg/kg)						
Total organic carbon	-[b]	350000	553000	402000	316000	244000
Total chlorides	-[b]	9.7	6.8	14.1	14.6	16.0
Total organic halides	-[b]	375	18.3	32.1	19.8	133

- = Not analyzed.

[a] This concentration is considered to be an analytical error based on the results for the other sample sets.

[b] Matrix spike data are not available; thus, concentrations are not corrected for accuracy.

Note: This table shows the concentrations or maximum potential concentrations in the kiln ash for all constituents that were detected in the untreated waste or detected in residuals generated from treatment of the waste. EPA analyzed the kiln ash for all the BDAT list constituents that are listed in Table D-2.

Table B-3 Matrix Spike Recovery Data for Scrubber Water Residuals from Rotary Kiln Incineration of K087 Waste

Constituent	Sample percent recovery	Duplicate percent recovery
Volatile Organics		
1,1-Dichloroethane	110	106
Trichloroethene	114	112
Chlorobenzene	112	106
Toluene	124	124
Benzene	106	108
(Average of volatiles)	(113.2)	(111.2)
Semivolatile Organics (acid-extractable)		
Pentachlorophenol	107	85
Phenol	96	93
2-Chlorophenol	106	108
4-Chloro-3-methylphenol	107	103
4-Nitrophenol	117	118
(Average of acid-extractables)	(106.6)	(101.4)
Semivolatile Organics (base/neutral-extractable)		
1,2,4-Trichlorobenzene	77	85
Acenaphthene	104	94
2,4-Dinitrotoluene	125	124
Pyrene	143	136
N-Nitroso-di-n-propylamine	104	98
1,4-Dichlorobenzene	78	87
(Average of base/neutral extractables)	(105.2)	(104)
Metals (total concentration)		
Antimony	110	117
Arsenic	83	64
Barium	94	88
Beryllium	87	87
Cadmium	94	92
Chromium	91	94
Copper	94	98
Lead	84	87
Mercury	58	58
Nickel	84	89
Selenium	108	90
Silver	76	80
Thallium	20	18
Vanadium	96	98
Zinc	88	91
Inorganics		
Cyanide	88	78

Table B-4 Accuracy-Corrected Analytical Results for Scrubber Water Generated by Rotary Kiln Incineration of K087 Waste

Constituent/parameter (units)	Correction factor	Concentration[a] Sample 1	2	3	4	5	6
BDAT Volatile Organics (μg/l)							
Benzene	1/1.00	<5	<5	<5	<5	<5	<5
Methyl ethyl ketone	1/1.00	14	<10	<10	<10	<10	<10
Toluene	1/1.00	<5	8	<5	<5	<5	<5
Xylenes	1/1.00	<5	<5	<5	<5	<5	<5
BDAT Semivolatile Organics (μg/l)							
Acenaphthalene	1/1.00	<10	<10	<10	<10	<10	<10
Anthracene	1/1.00	<10	<10	<10	<10	<10	<10
Benz(a)anthracene	1/1.00	<10	<10	<10	<10	<10	<10
Benzo(b)fluoranthene	1/1.00	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene	1/1.00	<10	<10	<10	<10	<10	<10
Benzo(a)pyrene	1/1.00	<10	<10	<10	<10	<10	<10
Chrysene	1/1.00	<10	<10	<10	<10	<10	<10
para-Cresol	1/1.00	<10	<10	<10	<10	<10	<10
Fluoranthene	1/1.00	<10	<10	<10	<10	<10	<10
Fluorene	1/1.00	<10	<10	<10	<10	<10	<10
Indeno(1,2,3-cd)pyrene	1/1.00	<10	<10	<10	<10	<10	<10
Naphthalene	1/1.00	<10	<10	<10	<10	<10	<10
Phenanthrene	1/1.00	<10	<10	<10	<10	<10	<10
Phenol	1/0.93	<11	<11	<11	<11	<11	<11
Pyrene	1/1.00	<10	<10	<10	<10	<10	<10
BDAT Metals (mg/l)							
Antimony	1/1.00	<0.032	<0.033	<0.020	0.039	<0.020	<0.032
Arsenic	1/0.64	0.330	0.298	0.231	0.402	0.469	0.534
Barium	1/0.88	0.074	0.398	0.343	0.386	0.330	0.116
Beryllium	1/0.8	<0.001	0.001	<0.006	<0.006	<0.006	<0.001
Cadmium	1/0.9	0.028	0.016	0.023	0.045	0.046	0.055
Chromium	1/0.91	0.336	0.334	0.170	0.259	0.280	0.285
Copper	1/0.94	1.117	1.170	1.008	1.319	1.234	1.319
Lead	1/0.84	6.679	8.333	3.857	5.690	6.679	5.762
Mercury	1/0.58	0.0004	<0.0003	0.0008	0.0006	0.0005	0.0007
Nickel	1/0.84	<0.013	<0.13	<0.048	<0.048	<0.048	<0.013
Selenium	1/0.90	0.090	0.068	0.006	0.092	0.097	0.097
Silver	1/0.76	<0.008	<0.009	<0.066	<0.066	<0.066	<0.008
Thallium	-[b]	126	109	77	108	96	136
Vanadium	1/0.96	0.016	0.013	<0.052	<0.052	<0.052	0.019
Zinc	1/0.88	2.557	2.318	1.977	3.307	3.034	3.364

Table B-4 (Continued)

Constituent/parameter (units)	Correction factor	Concentration[a] Sample 1	2	3	4	5	6
BDAT Inorganics Other Than Metals (mg/l)							
Cyanide	1/0.78	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
Fluoride	-[c]	3.38	2.99	2.38	-	-	3.54
Sulfide	-[c]	<1.0	<1.0	11.9	<1.0	<1.0	<1.0
Other Volatile Organics (μg/l)							
Styrene	1/1.00	<5	<5	<5	<5	<5	<5
Other Semivolatile Organics (μg/l)							
Dibenzofuran	1/1.00	<10	<10	<10	<10	<10	<10
2-Methylnaphthalene	1/1.00	<10	<10	<10	<10	<10	<10
Other Parameters							
Total organic carbon (mg/l)	-[c]	37.9	26.1	88.9	148	111	94.1
Total solids (mg/l)	-[c]	2240	2080	1910	2350	2480	2720
Total chlorides (mg/l)	-[c]	51.3	57.9	48.5	51.0	56.3	56.0
Total organic halides (μg/l)	-[c]	33.7	33.2	46.7	23.3	27.6	27.4

- = Not analyzed.

[a] Scrubber water samples are not assigned a sample set number. See the K087 OER (USEPA 1988a) for specific collection times.

[b] Matrix spike recoveries do not meet BDAT program criteria; these thallium concentrations are not corrected for accuracy.

[c] Matrix spike data are not available; thus, concentrations are not adjusted for accuracy.

Note: This table shows concentrations or maximum potential concentrations in the scrubber water for all constituents detected in the untreated waste or detected in residuals generated from treatment of the waste. EPA analyzed the scrubber water for all the BDAT list constituents that are listed in Table D-3.

Table B-5 Accuracy-Corrected Data for Treated Wastewater Residuals from Chemical Precipitation and Sludge Filtration

Constituent	Untreated concentration range[a] (mg/l)	Correction factor	Accuracy-corrected concentration (mg/l)										
			Sample Set #										
			1	2	3	4	5	6	7	8	9	10	11
Antimony	<10	1/0.92	(No substantial treatment)										
Arsenic	<1	1/1.00	(No substantial treatment)										
Barium	<10	1/0.90	<1.1	<1.1	<3.9	<11	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Beryllium	<2	1/0.90	(No substantial treatment)										
Cadmium	<5-13	1/0.87	<0.57	<0.57	<0.57	<5.7	<0.57	<0.57	<0.57	<0.57	<0.57	<0.57	<5.7
Hexavalent chromium[b]	0.08-893	1/1.06	0.010	0.179	_c	0.040	0.055	_c	0.114	<0.009	0.039	0.100	<0.009
Chromium	137-2581	1/0.68	0.176	0.176	0.294	0.147	0.162	0.147	0.176	0.221	0.147	0.176	0.265
Copper	72-225	1/0.83	0.253	0.181	0.253	0.084	0.169	0.145	0.193	0.193	0.096	0.169	0.289
Lead	<10-212	1/0.76	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
Mercury	≤1	1/0.90	(No substantial treatment)										
Nickel	382-16330	1/0.93	0.355	0.355	0.355	0.355	0.333	0.355	0.430	0.387	0.355	0.355	0.419
Selenium	<10	1/0.48	(No substantial treatment)										
Silver	<2	1/0.76	(No substantial treatment)										
Thallium	<10	1/0.84	(No substantial treatment)										
Zinc	3.9-171	1/0.98	0.128	0.117	0.143	1.653	0.128	0.097	0.117	0.133	0.061	0.071	0.102

[a] Untreated concentrations are not adjusted for accuracy.

[b] Hexavalent chromium was actually treated by chromium reduction prior to chemical precipitation and sludge filtration.

[c] Concentration could not be measured because of analytical interference.

Table B-6 Matrix Spike Recovery Data for Metals in Wastewater

Constituent	Original sample (µg/l)	Spike added (µg/l)	Sample: Spike result (µg/l)	Sample: Percent recovery[a]	Duplicate: Spike result (µg/l)	Duplicate: Percent recovery[a]
Antimony	<21	300	275	92	276	92
Arsenic	<10	50	70	140	66	132
Barium	1,420	5,000	5,980	91	5,940	90
Beryllium	1.4	25	25	94	24	90
Cadmium	4.2	25	26	87	27	91
Chromium	<4.0	50	35	70	34	68
Copper	<4.0	125	107	86	104	83
Lead	<5.0	25	22	88	19	76
Mercury	<0.2	1.0	0.9	90	1.1	110
Nickel	203	1,000	1,140	94	1,128	93
Selenium	<25	25	12	48	<25	NC
Silver	<4.0	50	42	84	38	76
Thallium	<10	50	51	102	48	96
Vanadium	<60	250	212	85	211	84
Zinc	2,640	10,000	12,600	100	12,400	98

NC = Not calculable.

[a] Percent recovery = [(spike result - original amount)/spike added] x 100.

Reference: USEPA 1988b.

Table B-7 Matrix Spike Recovery Data for the TCLP Extracts from Stabilization of F006 Waste

Constituent	Original amount found (ppm)	Duplicate (ppm)	% Error	Actual spike	% Recovery	Accuracy-correction factor
Arsenic	0.101^a	0.01	0.0	0.086	94.5	1.06
	0.01^b	0.01	0.0	0.068	104	0.96
Barium	0.3737^a	0.3326	5.82	4.9474	91.9	1.09
	0.2765^b	0.222	10.9	5.1462	97.9	1.02
Cadmium	0.0075^a	0.0069	4.17	4.9010	97.9	1.02
	2.9034^b	0.7555	58.7	6.5448	94.3	1.06
Chromium	0.3494^a	0.4226	9.48	4.6780	85.8	1.17
	0.2213^b	0.2653	9.0	4.5709	86.6	1.15
Copper	0.2247^a	0.2211	0.81	4.8494	92.5	1.08
	0.1526^b	0.1462	2.14	4.9981	97.0	1.03
Lead	0.3226^a	0.3091	2.14	4.9619	92.9	1.08
	0.2142^b	0.2287	3.27	4.6930	89.4	1.12
Mercury	0.001^a	0.001	0.0	0.0034	92	1.09
	0.001^b	0.001	0.0	0.0045	110	0.91
Nickel	0.028^a	0.0264	6.87	4.5400	90.3	1.11
	0.4742^b	0.0859	69.3	4.6093	86.6	1.15
Selenium^c	0.101^a	0.12	8.6	0.175	86	1.16
	0.043^b	0.053	10.4	0.095	66^d	0.96
Silver^c	0.0437^a	0.0399	4.55	4.2837	84.8	1.18
	0.0344^b	0.0411	8.87	0.081	0.87^d	114.9
Zinc	0.0133^a	0.0238	28.3	5.0910	101.4	0.99
	27.202^b	3.65	76.3	19.818	87.8	1.14

[a] At a mix ratio of 0.5.

[b] At a mix ratio of 0.2.

[c] For a mix ratio of 0.2, correction factors of 1.16 and 1.18 were used when correcting for selenium and silver concentrations, respectively.

[d] This value is not considered in the calculation for the accuracy-correction factor.

Reference: Memo to R. Turner, U.S. EPA/HWERL from Jesse R. Conner, Chemical Waste Management, dated January 20, 1988.

Table B-8 Accuracy-Corrected Performance Data for Stabilization of F006 Waste

Constituent	Stream	Concentration (ppm) Sample Set # 1	2	3	4	5	6	7	8	9
Arsenic	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	0.88
	Treated TCLP[a]	<0.01[d]	<0.01[c,d]	<0.01[c,d]	<0.01[c,d]	<0.01[c,d]	<0.01[c,d]	<0.01[c,d]	<0.01[c,d]	<0.02[c,d]
	Treated TCLP[b]	-	<0.01[d]	<0.01[d]	<0.01[d]	<0.01[d]	<0.01[d]	<0.01[d]	<0.01[d]	<0.02[d]
Barium	Untreated total	36.4	21.6	85.5	17.2	14.3	24.5	12.6	15.3	19.2
	Untreated TCLP	0.08	0.32	1.41	0.84	0.38	0.07	0.04	0.53	0.28
	Treated TCLP[a]	0.12[f]	0.51[c]	0.34	0.20[c]	0.32[c]	0.31[c]	0.04[c]	0.33[c]	0.19[c]
	Treated TCLP[b]	-	0.46[f]	0.34[c]	0.25	0.21	0.36[f]	0.15[f]	0.29	0.09
Cadmium	Untreated total	1.3	31.3	67.3	1.30	720	7.28	5.39	5.81	5.04
	Untreated TCLP	0.01	2.21	1.13	0.22	23.6	0.3	0.06	0.18	0.01
	Treated TCLP[a]	0.01[e]	0.53[c]	0.06	0.01[c]	3.43[c]	0.02[c]	0.01[c]	0.01[c]	<0.01[c]
	Treated TCLP[b]	-	0.01	0.02[c]	0.01	0.01	0.01	0.01	0.01	<0.01[e]
Chromium	Untreated total	1270	755	716	110	12200	3100	42900	47.9	644
	Untreated TCLP	0.34	0.76	0.43	0.18	25.3	38.7	360	0.04	0.01
	Treated TCLP[a]	0.59[f]	0.46[c]	0.09	0.27[c]	0.29[c]	0.24[c]	3.5[c]	0.11[c]	0.03[c]
	Treated TCLP[b]	-	0.45	0.23[c]	0.35[f]	0.44	0.88	1.41	0.23[f]	0.23[e]
Copper	Untreated total	40.2	7030	693	1510	160	1220	10600	17600	27400
	Untreated TCLP	0.15	368	1.33	4.6	1.14	31.7	8.69	483	16.9
	Treated TCLP[a]	0.20[f]	5.57[c]	1.69[f]	0.31[c]	0.21[c]	0.22[c]	0.41[c]	0.52[c]	3.28[c]
	Treated TCLP[b]	-	0.27	1.99[c]	0.29	0.31	0.22	0.45	0.34	0.50
Lead	Untreated total	35.5	409	25.7	88.5	52	113	156	169	24500
	Untreated TCLP	0.26	10.7	0.26	0.45	0.45	3.37	1.0	4.22	50.2
	Treated TCLP[a]	0.33[f]	0.45[c]	0.34[f]	0.34[c]	0.27[c]	0.34[c]	0.34[c]	0.35[c]	2.67[c]
	Treated TCLP[b]	-	0.39	0.44[c]	0.37[g]	0.39[g]	0.39	0.41	0.40	0.29

Table B-8 (Continued)

		Concentration (ppm) Sample Set #								
Constituent	Stream	1	2	3	4	5	6	7	8	9
Mercury	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
	Treated TCLP^a	$<0.001^d$	$<0.001^{c,d}$	$<0.001^d$	$<0.001^{c,d}$	$<0.001^{c,d}$	$<0.001^{c,d}$	$<0.001^{c,d}$	$<0.001^{c,d}$	$<0.001^{c,d}$
	Treated TCLP^b	-	$<0.001^d$	$<0.001^{c,d}$	$<0.001^d$	$<0.001^d$	$<0.001^d$	$<0.001^d$	$<0.001^d$	$<0.001^d$
Nickel	Untreated total	435	989	259	37	701	19400	13000	23700	5730
	Untreated TCLP	0.71	22.7	1.1	0.52	9.78	730	152	644	16.1
	Treated TCLP^a	0.05	1.73^c	0.26	0.12^c	0.61^c	19.1^c	0.46^c	18.1^c	1.25^c
	Treated TCLP^b	-	0.03	0.17^c	0.02	0.04	0.06	0.11	0.04	0.02
Selenium	Untreated total	-	-	-	-	-	-	-	-	-
	Untreated TCLP	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01	<0.45
	Treated TCLP^a	0.07^d	$0.07^{c,d}$	0.08^d	$0.09^{c,d}$	$0.05^{c,d}$	$0.06^{c,d}$	$0.05^{c,d}$	$0.08^{c,d}$	$<0.01^{c,d}$
	Treated TCLP^b	-	0.13^d	$0.13^{c,d}$	0.16^d	0.10^d	0.13^d	0.08^d	0.08^d	$<0.01^d$
Silver	Untreated total	2.3	6.62	39	9.05	5.28	4.08	12.5	8.11	19.1
	Untreated TCLP	0.01	0.14	0.02	0.16	0.08	0.12	0.05	0.31	<0.01
	Treated TCLP^a	0.04^e	0.04^c	0.24^f	0.04^c	0.05^c	0.04^c	0.04^c	0.04^c	$<0.01^c$
	Treated TCLP^b	-	0.06	0.06^c	0.05	0.07^g	0.06	0.06^f	0.06	$<0.01^e$
Zinc	Untreated total	1560	4020	631	90200	35900	27800	120	15700	322
	Untreated TCLP	0.16	219	5.41	2030	867	1200	0.62	650	1.29
	Treated TCLP^a	0.03	42.0^c	0.06	36^c	3.87^c	42.0^c	0.02^c	5.17^c	0.08^c
	Treated TCLP^b	-	0.01	0.03^c	0.04	0.03	0.04	0.02	0.02	<0.01

[a] Mix ratio is 0.2. The mix ratio is the ratio of the reagent weight to waste weight.

[b] Mix ratio is 0.5.

Note: Data points were deleted for the reasons given in the following footnotes:

[c] Less effective design and operation.

[d] No untreated total concentration or TCLP.

[e] Untreated TCLP value low.

[f] Treated values greater than untreated value.

[g] Reduction attributed to dilution with reagent.

Table B-9 Analytical Methods for Regulated Constituents

Analysis/methods	Method	Reference
Volatile Organics		
Purge-and-trap	5030	1
Gas chromatography/mass spectrometry for volatile organics	8240	1
Semivolatile Organics		
Continuous liquid-liquid extraction (treated waste)	3520	1
Soxhlet extraction (untreated waste)	3540	1
Gas chromatography/mass spectrometry for semivolatile organics: Capillary Column Technique	8270	1
Metals		
Acid digestion		
• Aqueous samples and extracts to be analyzed by inductively coupled plasma atomic emission spectroscopy (ICP)	3010	1
• Aqueous samples and standards to be analyzed by furnace atomic absorption (AA) spectroscopy	3020	1
• Sediments, sludges, and soils	3050	1
Lead (AA, furnace technique)	7421	1
Zinc (ICP)	6010	1
Toxicity Characteristic Leaching Procedure (TCLP)	51 FR 40643	2

References:

1. USEPA 1986a.
2. USEPA 1986b.

Table B-10 Specific Procedures or Equipment Used in Extraction of Organic Compounds When Alternatives or Equivalents Are Allowed in the SW-846 Methods

Analysis	SW-846 method	Sample aliquot	Alternatives or equivalents allowed by SW-846 methods	Specific procedures or equipment used
Purge-and-trap	5030	5 milliliters of liquid; 1 gram of solid	• The purge-and-trap device to be used is specified in Figure 1 of the method. The desorber to be used is described in Figures 2 and 3, and the packing materials are described in Section 4.10.2 of SW-846. The method allows equivalents of this equipment or materials to be used.	• The purge-and-trap equipment and the desorber used were as specified in SW-846. The purge-and-trap equipment were a Teckmar LSC-2 with standard purging chambers (Supelco cat. 2-0293). The packing materials for the traps were 1/3 silica gel and 2/3 2,6-diphenylene.
			• The method specifies that the trap must be at least 25 cm long and have an inside diameter of at least 0.105 cm.	• The length of the trap was 30 cm and the diameter was 0.105 cm.
			• The surrogates recommended are toluene-d8,4-bromofluorobenzene, and 1,2-dichloroethane-d4. The recommended concentration level is 50 μg/l.	• The surrogates were added as specified in SW-846.
Soxhlet Extraction	3540	1 gram of solid	• The recommended surrogates and their concentrations are the same as for Method 3520.	• The surrogates used and their concentration levels were the same as for Method 3520.
			• Sample grinding may be required for sample not passing through a 1-mm standard sieve or a 1-mm opening.	• Sample grinding was not required.

Table B-10 (Continued)

Analysis	SW-846 method	Sample aliquot	Alternatives or equivalents allowed by SW-846 methods	Specific procedures or equipment used
Continuous liquid-liquid extraction	3520	1 liter of liquid	• Acid and base/neutral extracts are usually combined before analysis by GC/MS. Under some situations, however, they may be extracted and analyzed separately.	• Acid and base/neutral extracts were combined.
			• The base/neutral surrogates recommended are 2-fluorobiphenyl, nitrobenzene-d5, and terphenyl-d14. The acid surrogates recommended are 2-fluorophenol, 2,4,6-tribromophenol, and phenol-d6. Additional compounds may be used for surrogates. The recommended concentrations for low-medium concentration level samples are 100 ppm for acid surrogates and 200 ppm for base/neutral surrogates. Volume of surrogate may be adjusted.	• Surrogates were the same as those recommended by SW-846, with the exception that phenol-d5 was substituted for phenol-d6. The concentrations used were the concentrations recommended in SW-846.

Table B-11 Specific Procedures or Equipment Used for Analysis of Organic Compounds When Alternatives or Equivalents Are Allowed in the SW 846 Methods

Analysis	SW-846 method	Sample preparation method	Alternatives or equivalents allowed in SW-846 for equipment or in procedure		Specific equipment or procedures used	
Gas chromatography/ mass spectrometry for volatile organics	8240	5030	Recommended GC/MS operating conditions:		Actual GC/MS operating conditions:	
			Electron energy:	70 ev (nominal)	Electron energy:	70 ev
			Mass range:	35-260 amu	Mass range:	35-260 amu
			Scan time:	To give 5 scans/peak but not to exceed 7 sec/scan	Scan time:	2.5 sec/scan
			Initial column temperature:	45°C	Initial column temperature:	38°C
			Initial column holding time:	3 min	Initial column holding time:	2 min
			Column temperature program:	8°C/min	Column temperature program:	10°C/min
			Final column temperature:	200°C	Final column temperature:	225°C
			Final column holding time:	15 min	Final column holding time:	30 min or xylene elutes
			Injector temperature:	200-225°C	Injector temperature:	225°C
			Source temperature:	According to manufacturer's specification	Source temperature:	manufacturer's recommended value of 100°C
			Transfer line temperature:	250-300°C	Transfer line temperature:	275°C
			Carrier gas:	Hydrogen at 50 cm/sec or helium at 30 cm/sec	Carrier gas:	Helium at 30 ml/min
			The column should be 6 ft x 0.1 in I.D. glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh) or an equivalent.		The column used was an 8 ft x 0.1 in I.D. glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh).	
			Samples may be analyzed by purge-and-trap technique or by direct injection.		The samples were analyzed using the purge-and-trap technique.	
					Additional information on actual system used: Equipment: Finnegan model 5100 GC/MS/DS system Data system: SUPERINCOS Autoquan Mode: Electron impact NBS library available Interface to MS - Jet separator	

Table B-11 (Continued)

Analysis	SW-846 method	Sample preparation method	Alternatives or equivalents allowed in SW-846 for equipment or in procedure		Specific equipment or procedures used	
			Recommended GC/MS operating conditions:		Actual GC/MS operating conditions:	
Gas chromatography/ mass spectrometry for semivolatile organics: capillary column technique	8270	3520-liquids 3520-solids	Mass range:	35-500 amu	Mass range:	35-500 amu
			Scan time:	1 sec/scan	Scan time:	1 sec/scan
			Initial column temperature:	40°C	Initial column temperature:	30°C
			Initial column holding time:	4 min	Initial column holding time:	4 min
			Column temperature program:	40-270°C at 10°C/min	Column temperature program:	8°C/min to 275° and 10°C/min until 305°C
			Final column temperature hold:	270°C (until benzo[g,h,i,]perylene has eluted)	Final column temperature hold:	305°C
			Injector temperature:	250-300°C	Injector temperature:	240-260°C
			Transfer line temperature:	250-300°C	Transfer line temperature:	300°C
			Source temperature:	According to manufacturer's specification	Source temperature:	Manufacturer's recommendation (nonheated)
			Injector:	Grob-type, splitless	Injector:	Grob-type, spitless
			Sample volume:	1-2 µl	Sample volume:	1 µl of sample extract
			Carrier gas:	Hydrogen at 50 cm/sec or helium at 30 cm/sec	Carrier gas:	Helium at 40 cm/sec
			The column should be 30 m by 0.25 mm I.D., 1-µm film thickness silicon-coated fused silica capillary column (J&W Scientific DB-5 or equivalent).		The column used was a 30 m x 0.32 mm I.D. RT_x-5 (5% phenyl methyl silicone) FSCC.	
					Additional information on actual system used: Equipment: Finnegan model 5100 GC/MS/DS system Software Package: SUPERINCOS Autoquan	

Table B-12 Specific Procedures Used in Extraction of Organic Compounds When Alternatives to SW-846 Methods Are Allowed by Approval of EPA Characterization and Assessment Division

Analysis	SW-846 method	Sample aliquot	SW-846 specification	Specific procedures allowed by approval of EPA-CAD
Continuous liquid-liquid extraction	3520	1 liter	• The internal standards are prepared by dissolution in carbon disulfide and then dilution to such volume that the final solvent is 20% carbon disulfide and 80% methylene chloride.	• The preparation of the internal standards was changed to eliminate the use of carbon disulfide. The internal standards were prepared in methylene chloride only.
Soxhlet extraction	3540	1 gram	• The internal standards are prepared by dissolution in carbon disulfide and then dilution to such volume that the final solvent is 20% carbon disulfide and 80% methylene chloride.	• The preparation of the internal standards was changed to eliminate the use of carbon disulfide. The internal standards were prepared in methylene chloride only.

Table B-13 Deviations from SW-846

Analysis	Method	SW-846 specifications	Deviation from SW-846	Rationale for deviation
Soxhlet extraction	3540	Concentrate extract to 1-ml volume.	Extracts for untreated waste were concentrated to 5-ml volume.	The untreated waste samples could not be concentrated to 1-ml sample volume because of the viscosity of the extract.
Acid digestion for metals analyzed	3010 3020	Digest 100 ml of sample in a conical beaker.	Initial sample volume of 50 ml was digested in Griffin straight-side beakers. All acids and peroxides were halved.	Sample volume and reagents were reduced in half, therefore, time required to reduce sample to near dryness was reduced. However, this procedure produced no impact on the precision and accuracy of the data.

APPENDIX C

DESIGN AND OPERATING DATA FOR ROTARY KILN INCINERATION PERFORMANCE DATA

This appendix is a presentation and analysis of the design and operating data from the Onsite Engineering Report of Treatment Technology and Performance for K087 Waste at the Combustion Research Facility, Jefferson, Arkansas (USEPA 1988a.)

The operating data presented in Table C-1 are reported according to the sample set time interval during which they were collected. The desired operating conditions or targeted values for the test burn are displayed under the headings. The targeted values represent the optimum operating conditions that are believed to provide the most effective destruction of the organic constituents of concern in the Combustion Research Facility (CFR) rotary kiln system.

Table C-1 indicates that the kiln rotational speed, the scrubber effluent water temperature, the pressure across the venturi scrubber, and the scrubber effluent water pH and flow rate were kept with the targeted values. The operating data for the kiln and afterburner temperatures and for the gaseous emissions show some fluctuations from the targeted values. Also, the operating data for the feed rate indicate that there are fluctuations inherent in the operation of the rotary kiln system. All these fluctuations from the targeted values are discussed below.

Tables C-2 and C-3 summarize the time intervals during which the temperature in the kiln or the afterburner fell below the targeted values. These data have been estimated from the strip charts at the end of this appendix.

The targeted temperature in the primary chamber of the rotary kiln at the CRF was 1800°F. This temperature represents the maximum temperature attainable in the primary chamber of the CRF kiln. During treatment, there were a number of deviations from the targeted temperature. Considering the range and frequency of these deviations and examining the concentratons of organics in the kiln ash, EPA has concluded that the conditions in the primary chamber represent a well-operated unit for treatment of the K087 waste. A discussion of the deviations from the targeted temperature is presented below.

As shown during the test sample set time intervals, temperatures in the kiln fell below the targeted 1800°F on 16 occasions for periods lasting from 3 to 90 minutes. The most severe fluctuation occurred on August 26 1987, when the temperature climbed from 1350 to 1800°F over a period of approximately 70 minutes.

The targeted temperature for the afterburner was 2150°F; this temperature represents the maximum attainable value for the CRF. During treatment, the operating temperature deviated from the targeted condition on several occasions.

Both the kiln and the afterburner at the CRF were equipped with ultraviolet sensors that automatically terminated the auxilliary fuel and air flows (and signaled to the operator to stop feeding waste into the kiln) when a flameout (loss of visible flame) was detected. Note that false detection of a flameout resulted in an actual flameout because the auxiliary fuel and excess air were turned off. Flameouts were detected on several occasions during the sample set time intervals of the K087 test burn, as indicated on Table C-4.

The Agency believes these flameouts represent typical fluctuations during normal operations of rotary kiln incinerators, especially in systems where containerized waste is ram fed into the incinerator at discrete time intervals. During the sample set time intervals, the kiln and afterburner flames were reignited within seconds. As evidenced by the data, a flameout usually results in a decrease in temperature and, if the flameout occurs in the afterburner, a drop in oxygen and a rise in carbon dioxide content in the gas stream from the afterburner. Note that there were occasions when the continuous emissions monitoring instrumentation indicated less than 1 percent oxygen and greater than 100 ppm carbon monoxide in the gas stream from the afterburner. (Table C-5 summarizes the estimated times.) These occasions, however, were extremely short-lived, as indicated by the spike-like behavior of the curves on the Figure B and D strip charts, which are presented in this appendix.

Oxygen and carbon monoxide spikes also were produced when temperatures climbed sharply in the kiln; according to CRF engineers, these spiking phenomena were caused by "hot charged" fed into the kiln. (A fiber drum was considered to be a "hot charge" if its K087 heating value exceeded that of the average fiber drum.) These spikes would not be considered uncommon in an operation such as the CRF rotary kiln system, which has a ram-feed mechanism.

The operator at the ram feeder was instructed to stop the feed immediately after each flameout occurrence or period of dramatic temperature increase until the system stabilized. Thus, while the feed rate averaged over the feeding period of each sample set interval was less than the targeted value, it does not indicate poor operation.

Having evaluated the operating data, the Agency believes that the rotary kiln incineration system was well operated and that the analytical data are useful for the development of treatment standards for K087 waste.

Table C-1 Operating Data from the K087 Test Burn

Sample Set/ Date	Time	Kiln rotational speed (rpm)	Temperature (°F)[a]			Feed rate[c] (lb/hr)	Emissions[b]				Pressure drop venturi (in H_2O)	Scrubber effluent water pH	Scrubber effluent water flow rate (gpm)
			Kiln	Afterburner	Scrubber effluent water		O_2 (% vol)	CO_2 (% vol)	CO[d] (ppm)	THC (ppm)			
Target values:[e]		0.2	1800	2150	<180	105	6-8	-	<1000	0	20	7.0-8.0	1.5
Sample Set #1 8/25/87	8:40-15:10	0.2	1400-2000	1950-2150	165-170	77	0-19	7.0->10	0->100	-[f]	9-17[g]	6.9-7.8	1.5
Sample Set #2 8/25/87 (scrubber effluent water data)	14:10-18:25	0.2	1600-2000	1850-2150	143-170	80	0-18	6.4->10	0->100	-[f]	7-14[g]	7.0-7.5	1.5
Sample Set #2 8/26/87 (kiln ash data)	10:20-13:00	0.2	1350-1875	1925-2150	165-170	97	0-13	3.8->10	0->100	0->10[h]	7-22[g]	7.0-7.6	1.5
Sample Set #3 8/28/87	9:50-14:15	0.2	1675-2000	1900-2150	165-170	89	0-14	5.4->10	0-1500	0->10[h]	20	7.2	1.5
Sample Set #4 8/28/87	13:15-16:50	0.2	1625-2000	2050-2150	165-170	87	2-12	6.8->10	0-800	0	20	7.2	1.5
Sample Set #5 8/28/87	15:50-18:25	0.2	1725-2050	2125-2175	165-170	90	4-12	6.4->10	0-360	0	20	7.2	1.5

Table C-1 (Continued)

[a] Kiln and afterburner temperatures presented on this table are minimum and maximum values according to the data logger strip charts, which are presented in Figures C-1 through C-5 in this Appendix. Note that the thermocouples connected to the American Combustion printer are used by the controller for adjusting operating conditions.

[b] The minimum O_2 and maximum CO values typically correspond to periods of flameout in the kiln and/or afterburner. See Figures B, C, and D (in Appendix C) for strip charts showing continuous emissions monitoring (CEM) of O_2, CO_2, and CO, respectively.

[c] Includes weight of fiber drum packaging (1.1 pounds per drum) and weight of waste (approximately 3.5 pounds per drum). Waste feed rate alone was targeted at 80 lb/hr.

[d] Upper end of detection limit for CO was raised from 100 ppm on August 25 and 26 to 2000 ppm on August 28 by switching to another strip chart recorder.

[e] The targeted values represent the optimum operating conditions to provide the most effective treatment for hazardous organic constituents. EPA recognizes that during normal operation, these optimum conditions cannot be sustained at all times. EPA will determine whether the treatment system has been adequately operated based on the magnitude and duration of the fluctuations from the targeted values.

[f] THC analyzer was down for repairs.

[g] Needle readout failed during the test burn; operator speculated that pressure drop was in reality 20 in H_2O on 8/25 and 8/26. Operator recorded values from a second readout located in the bay area on 8/28.

[h] The analyzer registered four sharp peaks on 8/26 at approximately 10:25, 10:28, 11:00, and 11:40 and one sharp peak on 8/28 at approximately 09:59.

Reference: USEPA 1988a.

Table C-2 Summary of Intervals When Temperatures in the Kiln Fell Below Targeted Value of 1800°F

Date	Interval[a]	Minimum temperature reached during interval (°F)[a]	Observations
8/25/87	08:41 - 08:57	1400	Flameout (08:41)
	08:57 - 09:27	1450	Flameout (08:57, 09:12)
	10:03 - 10:15	1650	Flameout (10:02)
	11:36 - 12:12	1675	Flameout (12:00)
	12:37 - 12:40	1750	Flameout (12:37)
	15:07 - 15:12	1725	-
	17:04 - 18:25	1600	Flameout (17:02-18:25)
8/26/87	10:20 - 11:27	1350	Ash bin replaced at 10:00
	11:27 - 11:39	1725	-
	11:39 - 12:00	1650	Flameout (11:40, 11:42)
8/28/87	09:50 - 09:59	1725	-
	10:01 - 10:05	1725	Flameout (10:00)
	10:07 - 10:13	1675	Flameout (10:07)
	10:14 - 10:20	1725	Flameout (10:14)
	14:41 - 15:08	1625	-
	16:08 - 16:14	1725	-

[a] Intervals and minimum temperatures are estimated from strip charts in Figures C-1 through C-5, which are presented in this appendix.

Table C-3 Summary of Intervals When Temperatures in the Afterburner Fell Below Targeted Value of 2050°F

Date	Interval[a]	Minimum temperature reached during interval (°F)[a]	Observations
8/25/87	08:41 - 08:47	2025	
	08:57 - 10:00	1950	Flameout (08:57)
	10:00 - 10:30	1975	Flameout (10:02)
	10:48 - 11:00	2050	Flameout (10:50)
	11:33 - 11:48	2000	-
	12:35 - 12:45	2050	Flameout (12:37)
	13:03 - 13:09	2050	Flameout 13:07)
	15:34 - 15:42	2050	Flameout (15:30, 15:37)
	15:58 - 16:27	2025	Flameout (16:00)
	16:45 - 16:54	2025	Flameout (16:42, 16:47)
	17:03 - 17:20	1850	Flameout (17:02)
8/26/87	10:30 - 11:02	2000	Flameout (10:30)
	11:02 - 11:24	1950	Flameout (11:02)
	11:39 - 12:00	1925	Flameout (11:40, 11:42)
8/28/87	09:50 - 10:33	1900	Flameout (10:00)
	10:33 - 10:53	2000	Flameout (10:37)
	14:41 - 15:11	2075	-
	16:08 - 16:30	2125	-
	17:02 - 17:17	2125	-
	17:32 - 18:25	2125	-

[a] Intervals and minimum temperatures are estimated from strip charts in Figures C-1 through C-5, which are presented in this appendix.

Table C-4 Flameout Occurrences Recorded by Operator

Date	Operating log time	Location of flameout	
		Kiln	Afterburner
8/25/87	08:41		x
	08:57	x	x
	09:12		x
	10:02	x	x
	10:50		x
	12:00	x	x
	12:37		x
	13:07		x
	15:30		x
	15:37		x
	16:00		x
	16:42		x
	16:47		x
	17:02	x	
8/26/87	10:30		x
	11:02	x	x
	11:40	x	x
	11:42	x	
	13:36		x
8/28/87	10:00		x
	10:06		x
	10:13		x
	10:37		x
	11:10	x	
	12:56		x

Table C-5 Occurrences of Oxygen and Carbon Monoxide Spikes[a]

Date	Time of occurrence[b]	Less than 1% oxygen	Greater than 100 ppm carbon monoxide	Other observations
8/25/87	08:56	x	x	Flameout (08:57)
	09:08	x	x	Flameout (09:12)
	09:32	x	x	Hot charge
	09:35	x	x	Hot charge
	09:57	x	x	Hot charge
	10:00	x	x	Flameout (10:02)
	10:48	x	x	Flameout (10:50)
	11:33	x	x	Hot charge
	12:14	x	x	Hot charge
	12:32	x	x	Hot charge
	12:34	x	x	Flameout (12:37)
	12:54	x	x	Hot charge
	13:02	x	x	Flameout (13:07)
	13:14	x	x	Hot charge
	13:33	x	x	Hot charge
	15:31	x	x	Flameout (15:30)
	15:33	x	x	-
	15:38	x	x	Flameout (15:37)
	15:55	x	x	Flameout (16:00)
	16:13	x	x	-
	16:40	x	x	Flameout (16:42)
	16:45	x	x	Flameout (16:47)
8/26/87	10:25	x	-	Hot charge
	10:30	-	x	Flameout (10:30)
	10:56	x	-	Hot charge
	11:02	-	x	Flameout (11:02)
	11:35	x	-	-
	11:40	-	x	Flameout (11:40)
	12:35	x	-	Hot charge
	12:40	-	x	Hot charge
8/28/87	10:00	-	x	Flameout (10:00)
	10:06	-	x	Flameout (10:06)
	10:13	-	x	Flameout (10:13)
	10:34	-	x	Hot charge
	10:36	-	x	Flameout (10:37)
	11:07	x	x	Flameout (11:10)
	12:21	-	x	Hot charge
	12:56	x	x	Flameout (12:56)
	13:22	-	x	Hot charge
	14:27	-	x	Hot charge
	14:35	-	x	Hot charge
	15:09	-	x	Hot charge
	15:25	x	x	Hot charge
	15:33	-	x	Hot charge
	17:00	-	x	Hot charge

[a] Oxygen less than 1 percent and carbon monoxide greater than 100 ppm according to strip charts in Figures C-6 to C-8 and C-12 to C-16.

[b] Estimated from strip charts in Figures C-6 to C-16.

Temperature Trends for the Kiln Exit, Afterburner Exit, Venturi Exit and Scrubber Effluent Water

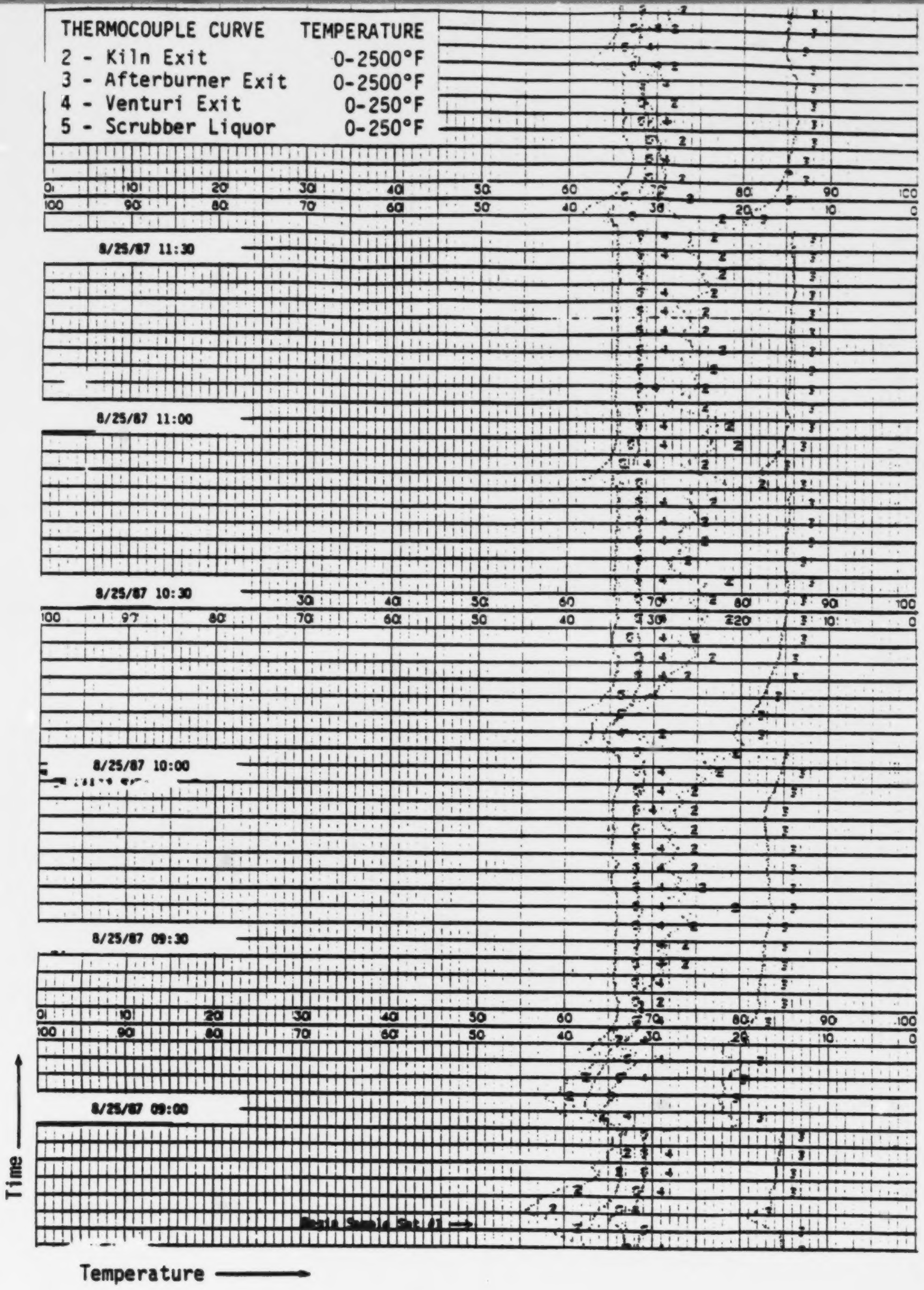

Figure C-1 Temperature Trends for Sample Set #1

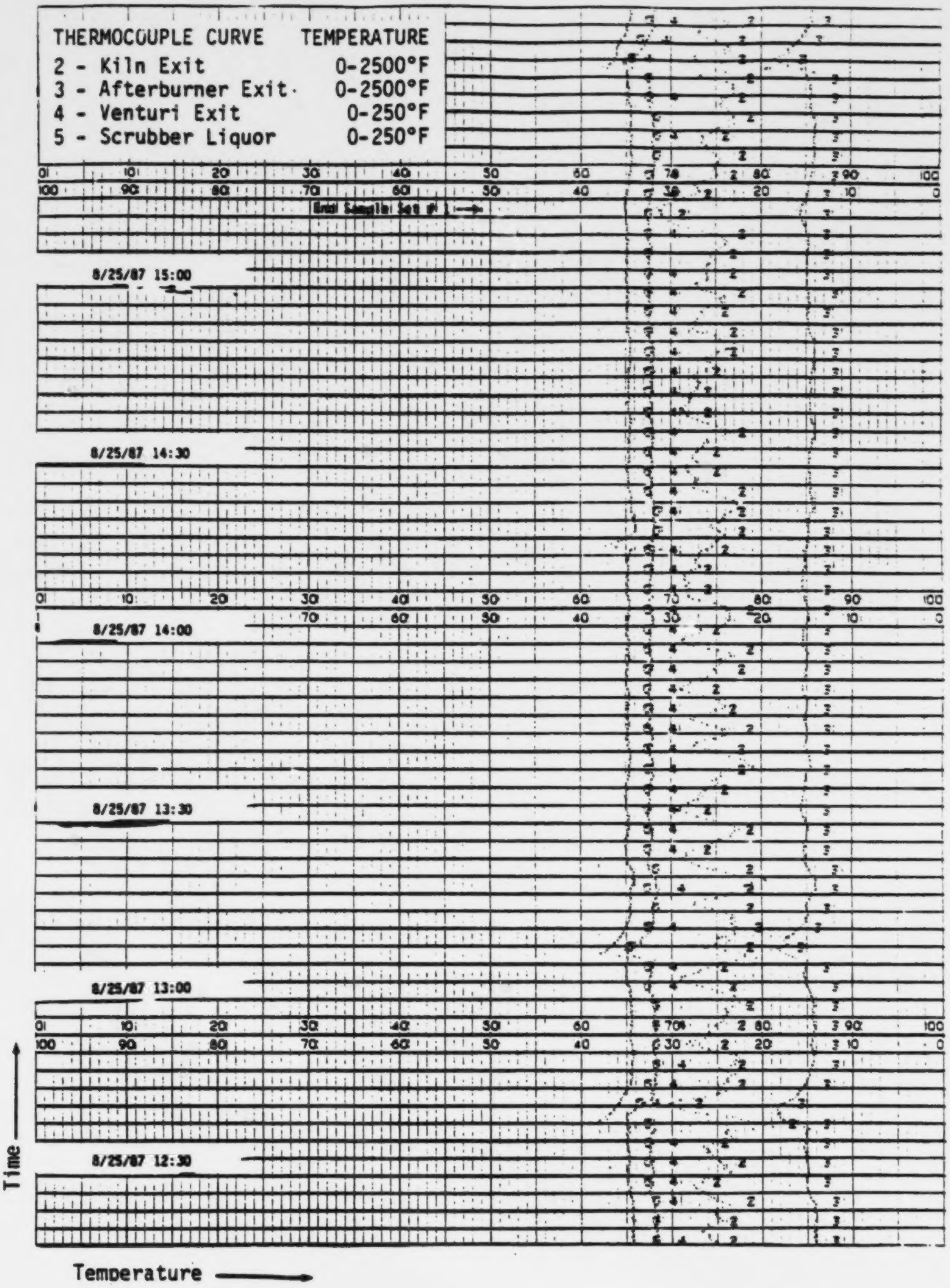

Figure C-1 (Continued)

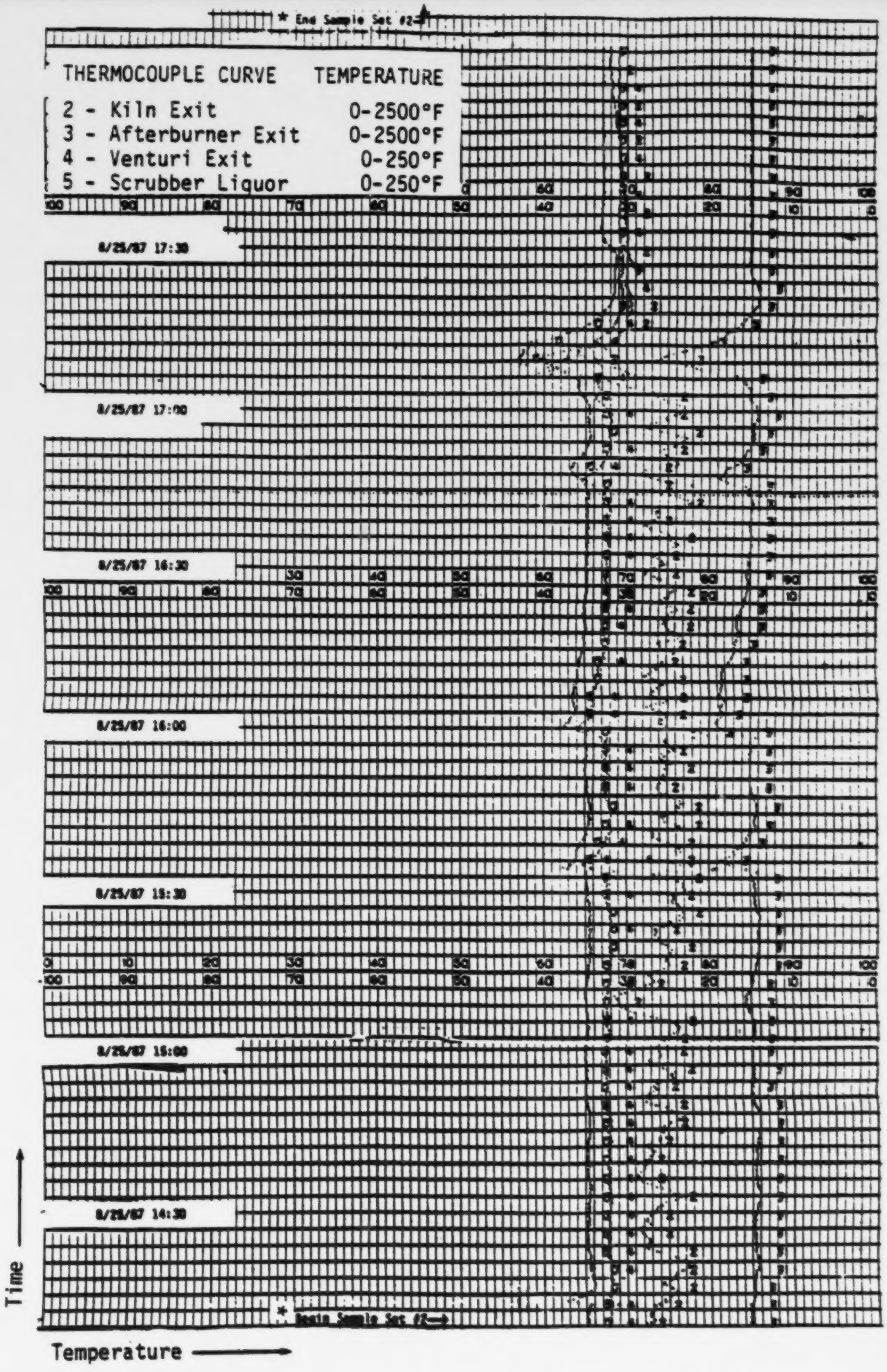

Figure C-2 Temperature Trends for Sample Set #2

*Data for scrubber effluent water collection.

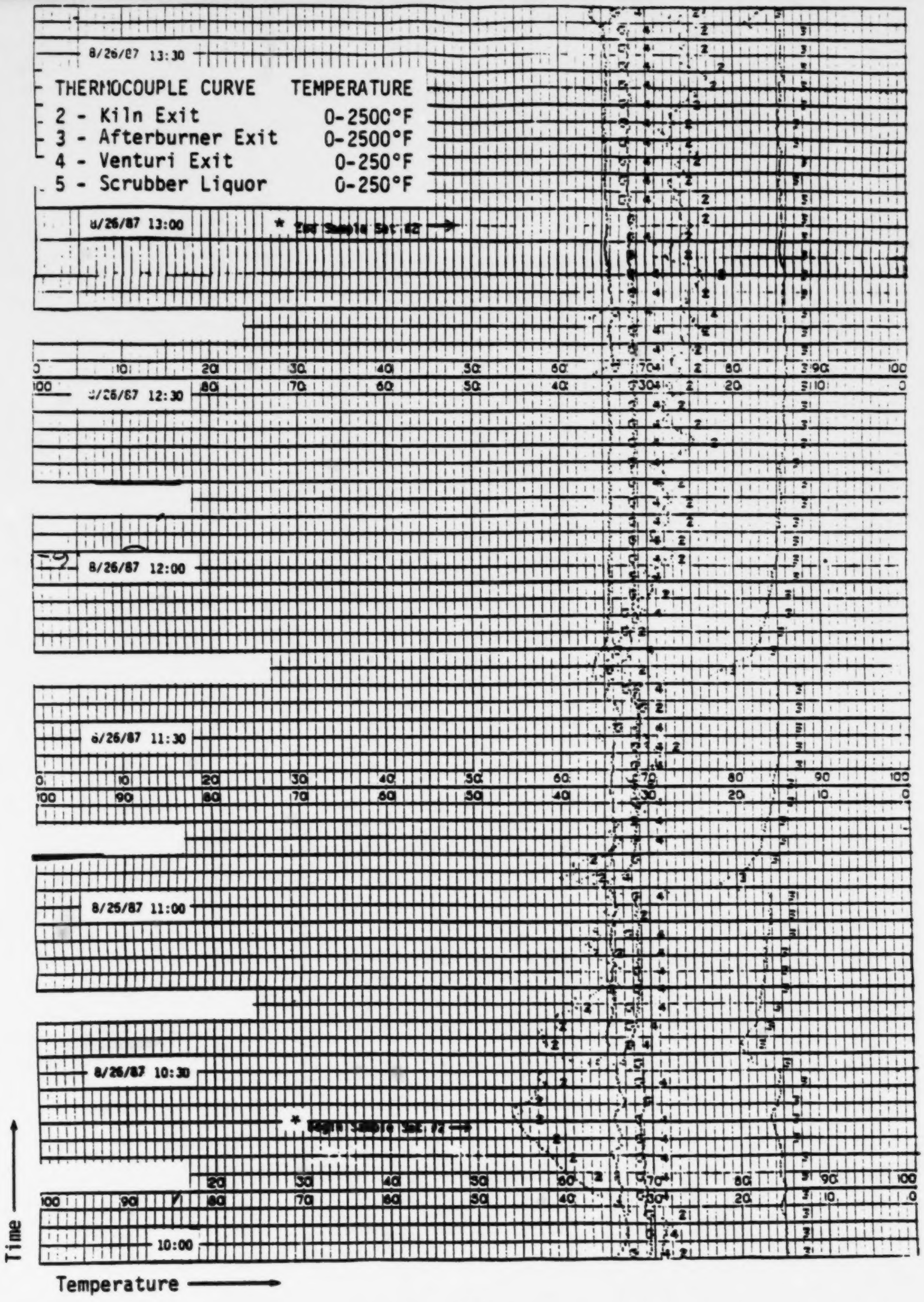

Figure C-2 (Continued)

*Data for kiln ash collection.

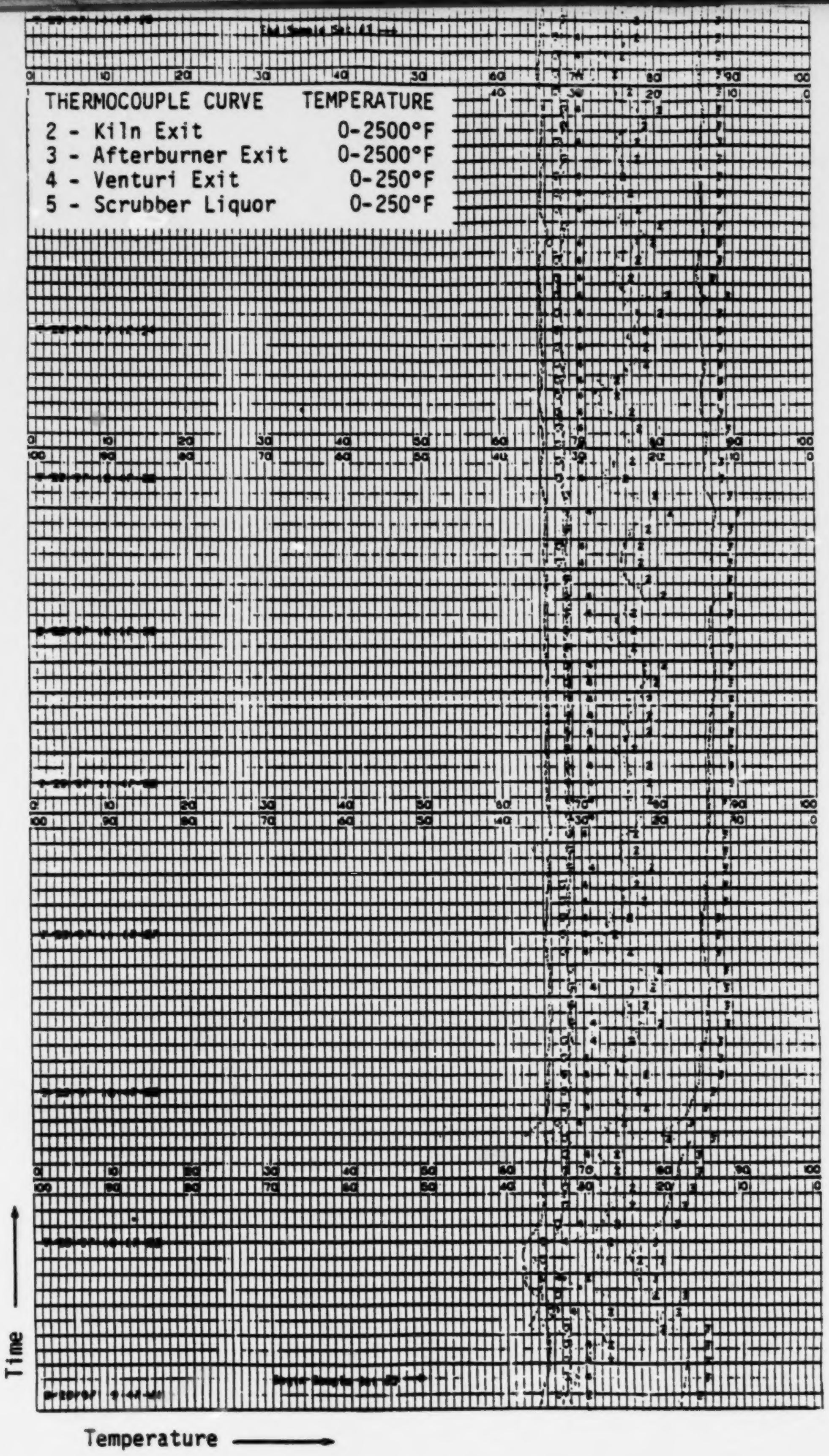

Figure C-3 Temperature Trends for Sample Set #3

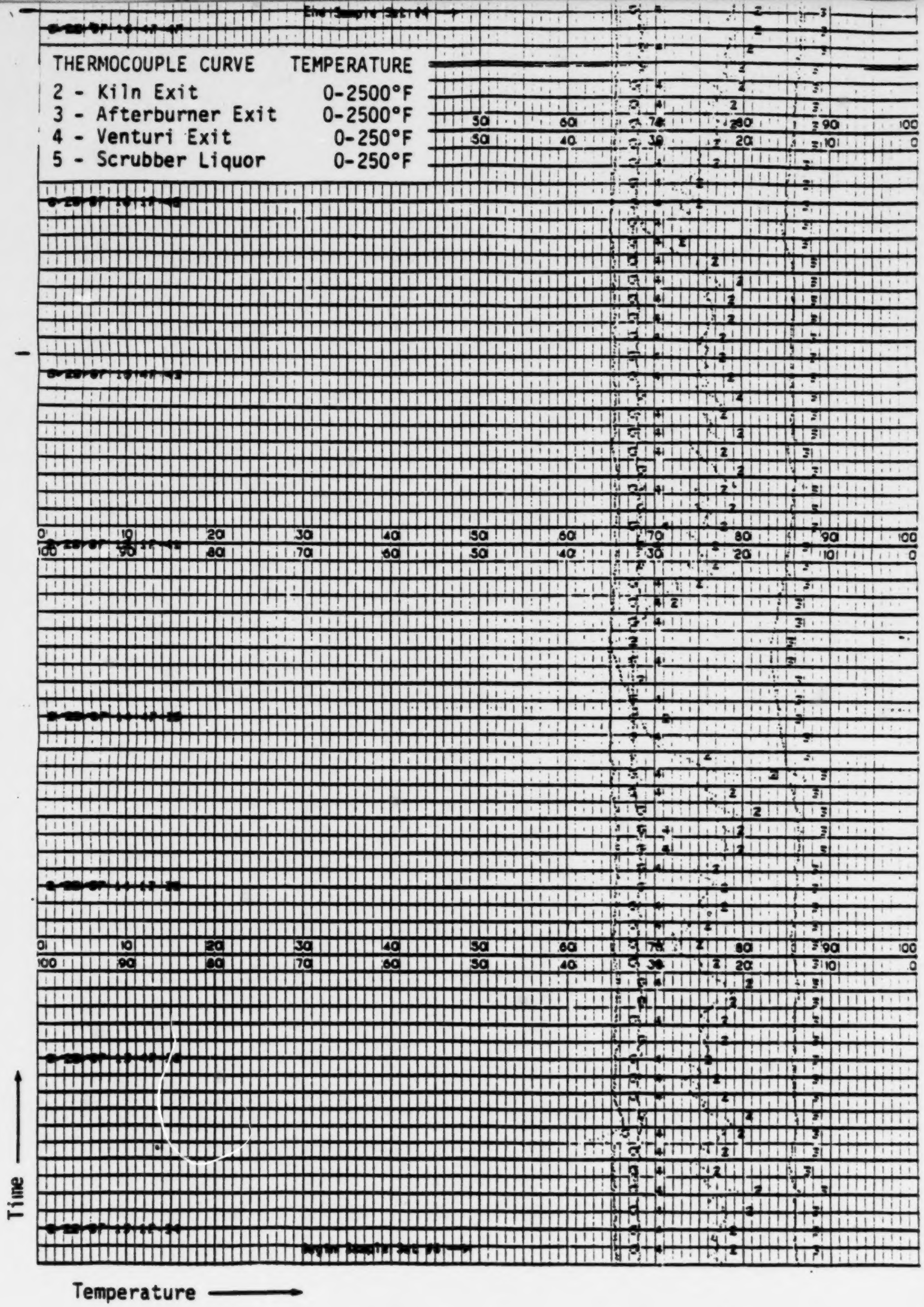

Figure C-4 Temperature Trends for Sample Set #4

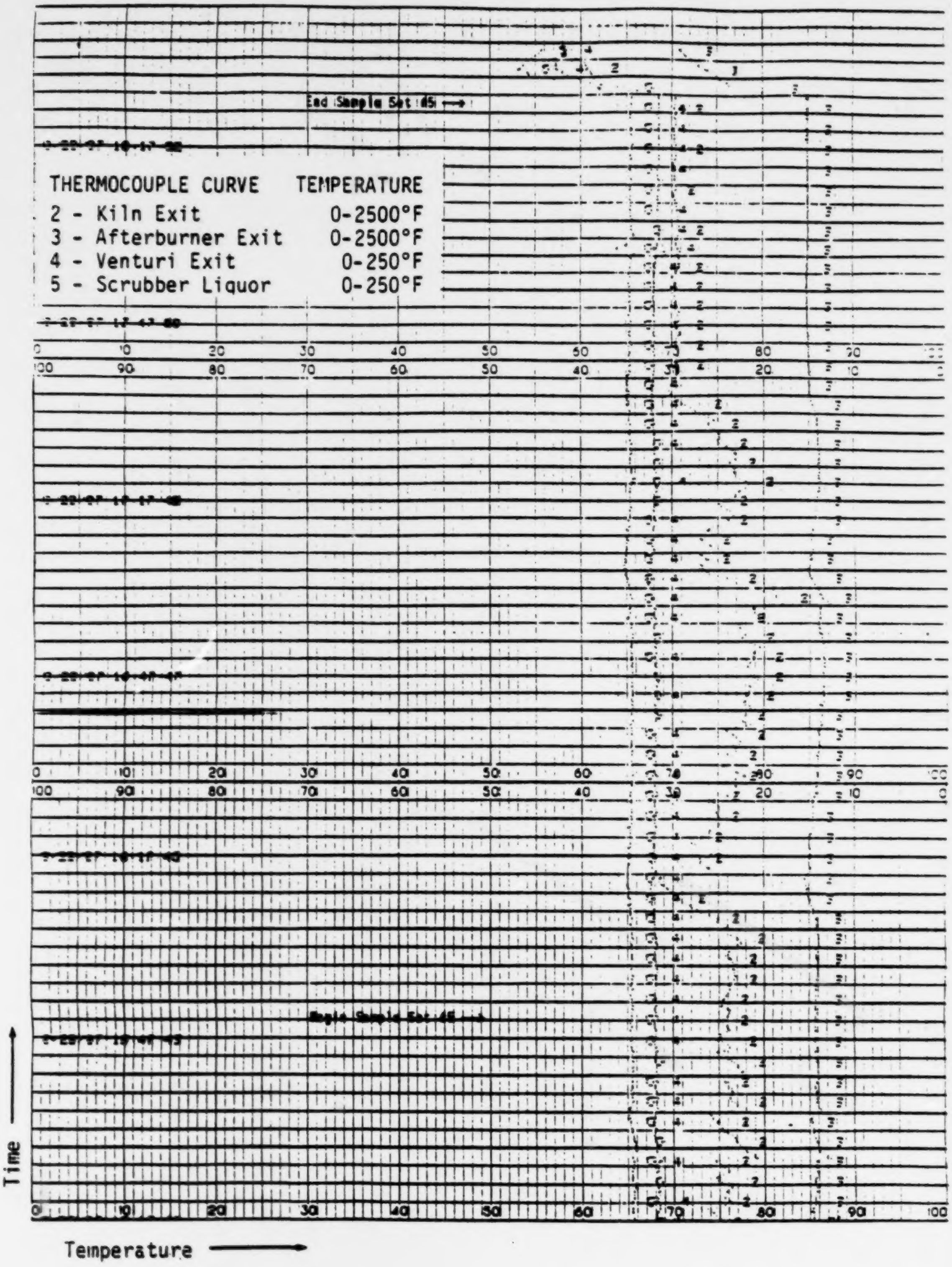

Figure C-5 Temperature Trends for Sample Set #5

Oxygen Emissions Strip Charts

OXYGEN EMISSIONS

8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-25% (vol)

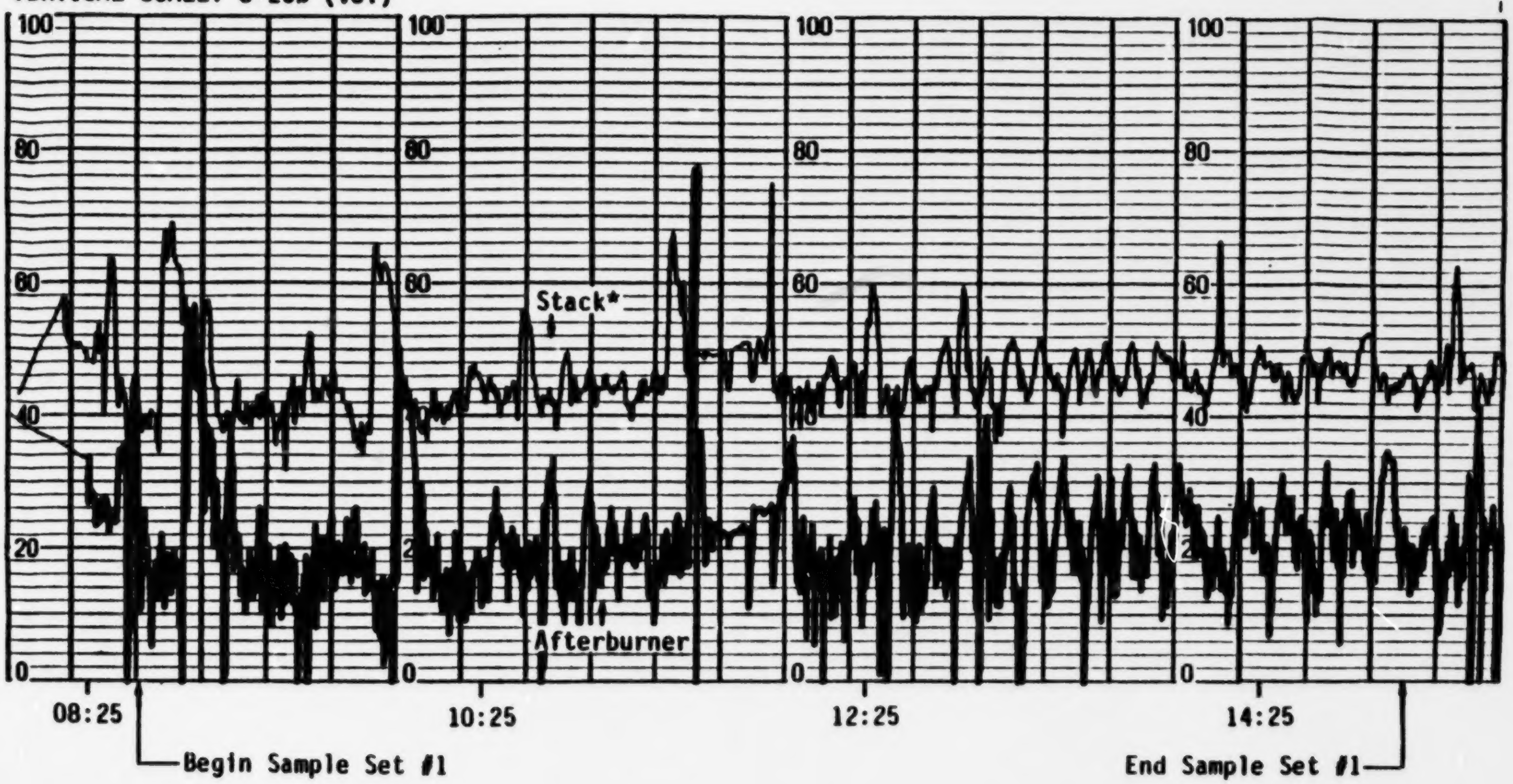

Figure C-6 Oxygen Emissions for Sample Set #1

*Recorder pens were not aligned vertically; thus, stack curve is shifted 10 minutes to the left

OXYGEN EMISSIONS

8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-25% (vol)

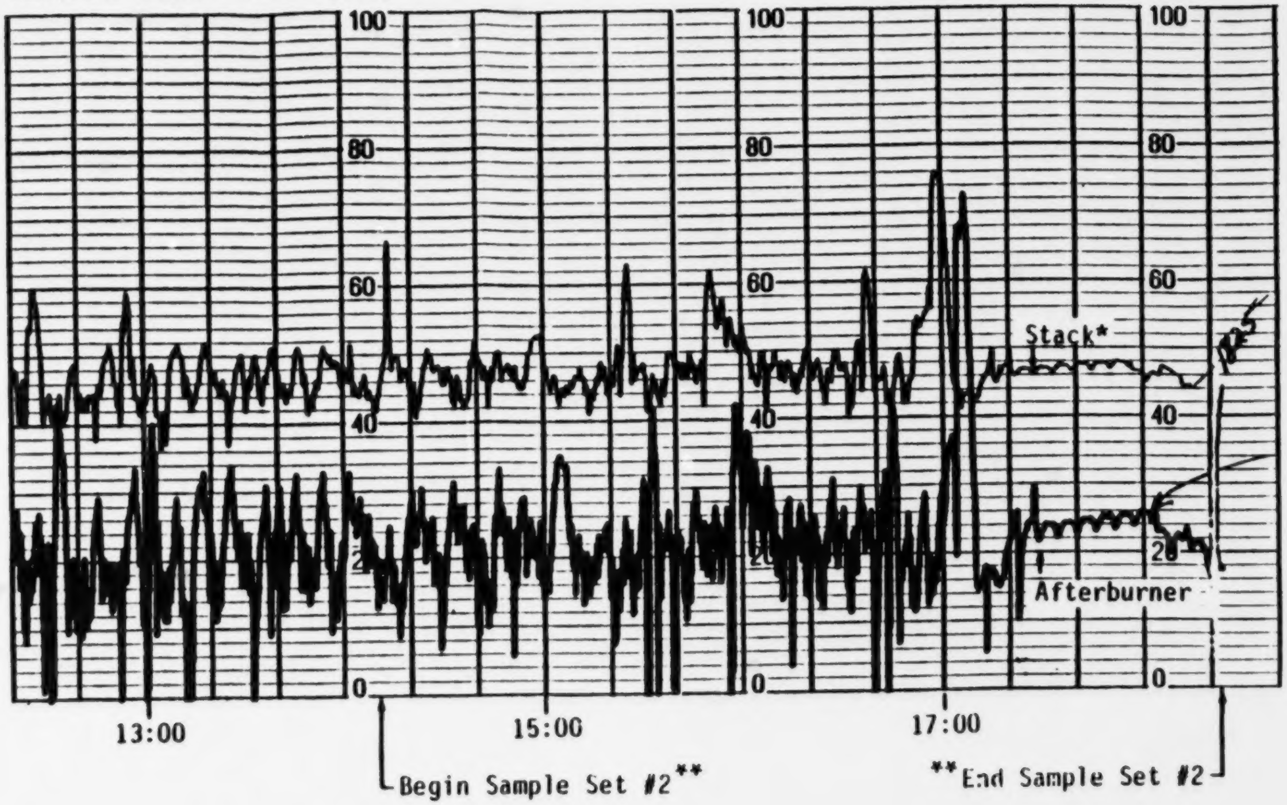

Figure C-7 Oxygen Emissions for Sample Set #2

*Recorder pens were not aligned vertically; thus, stack curve is shifted 10 minutes to the left.

OXYGEN EMISSIONS

8/26/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-25% (vol)

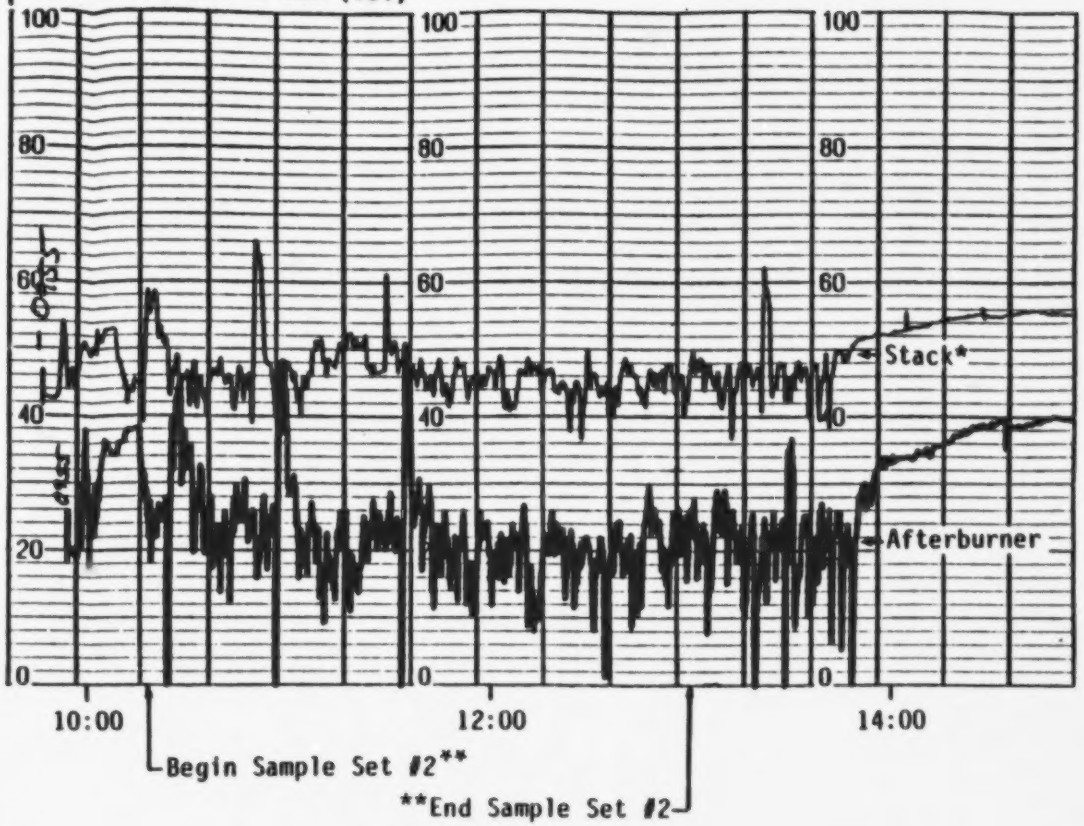

Figure C-7 (Continued)

*Recorder pens were not aligned vertically; thus, stack curve is shifted 5 minutes to the left.
**Data for kiln ash collection.

OXYGEN EMISSIONS

8/28/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-25% (vol)

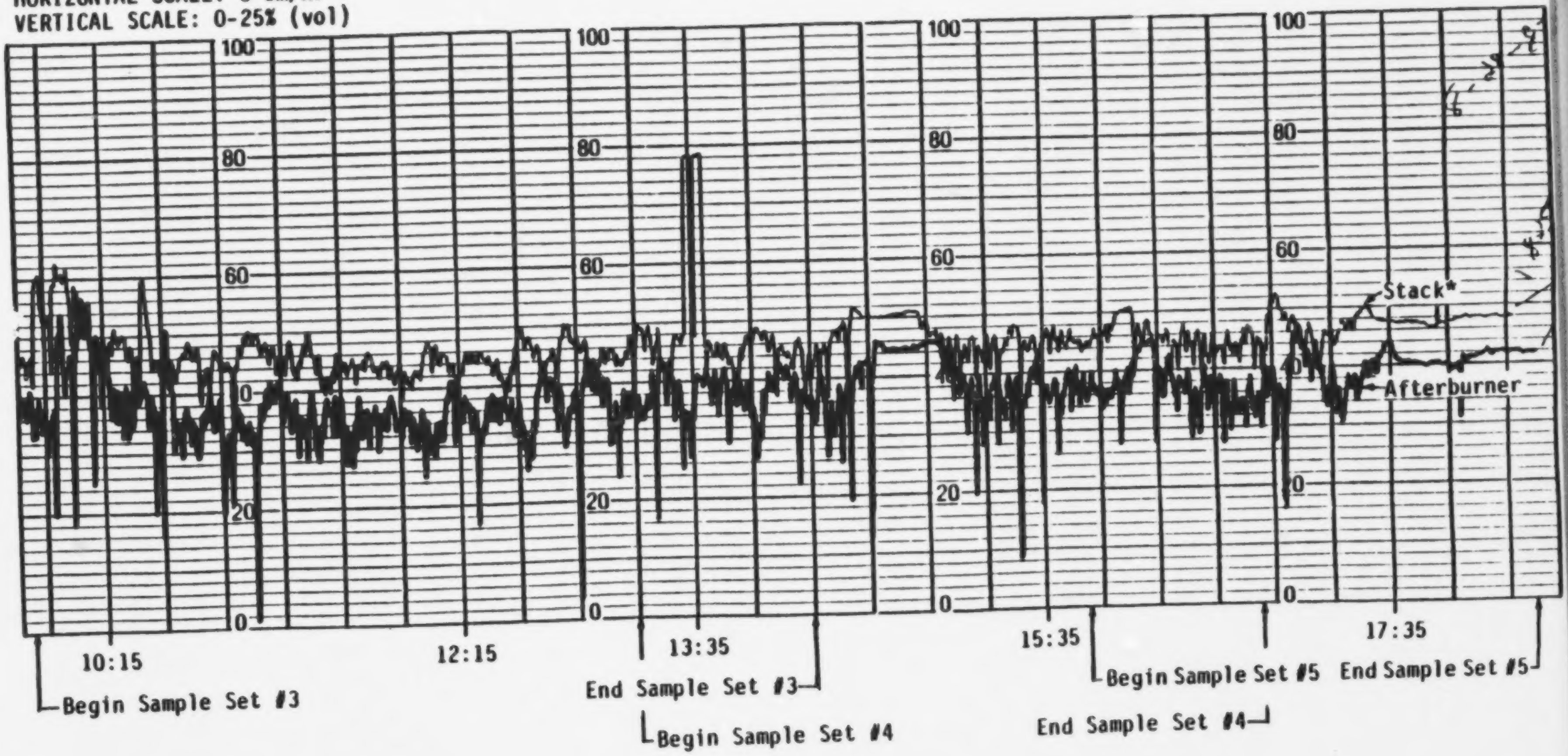

Figure C-8 Oxygen Emissions for Sample Sets #3, #4, and #5

* [illegible] tically; thus, stack curve is shifted 9 minutes to the left

Carbon Dioxide Emissions Strip Charts

CARBON DIOXIDE EMISSIONS

8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-10% (vol)

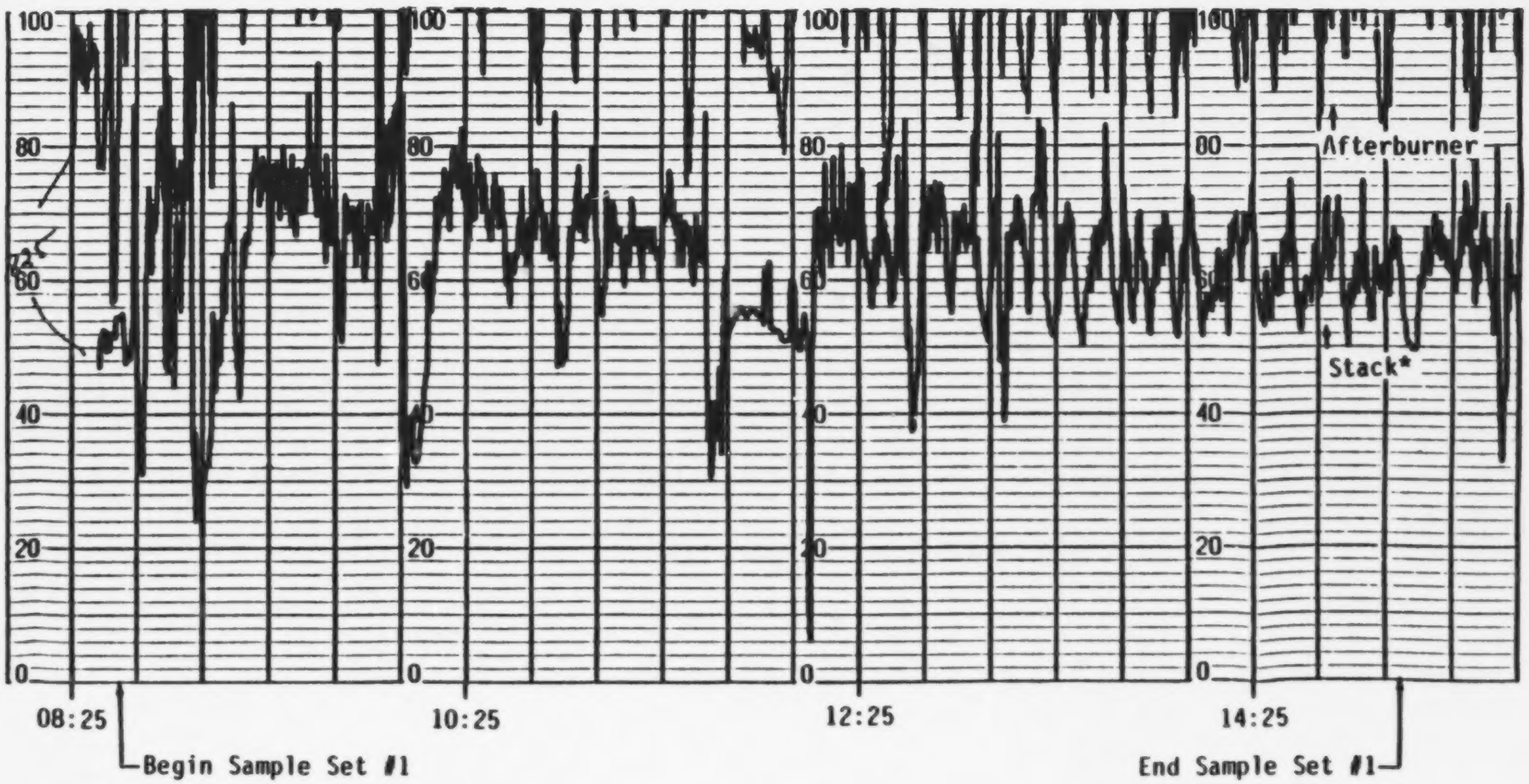

Figure C-9 Carbon Dioxide Emissions for Sample Set #1

*Recorder pens were not aligned vertically; thus, stack curve is shifted 8 minutes to the right.

CARBON DIOXIDE EMISSIONS

8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-10% (vol)

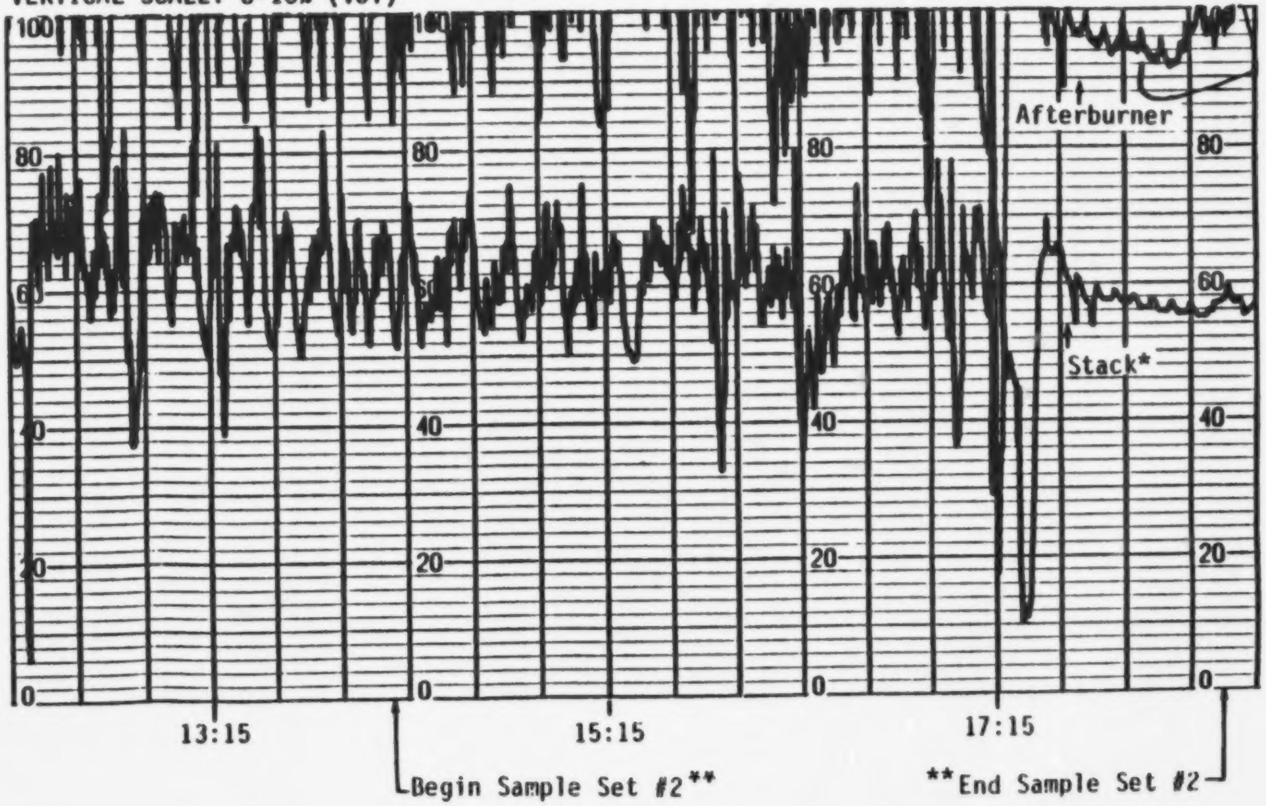

Figure C-10 Carbon Dioxide Emissions for Sample Set #2

*Recorder pens were not aligned vertically; thus, stack curve is shifted 8 minutes to the right.
**Data for scrubber effluent water collection.

CARBON DIOXIDE EMISSIONS

8/26/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-10% (vol)

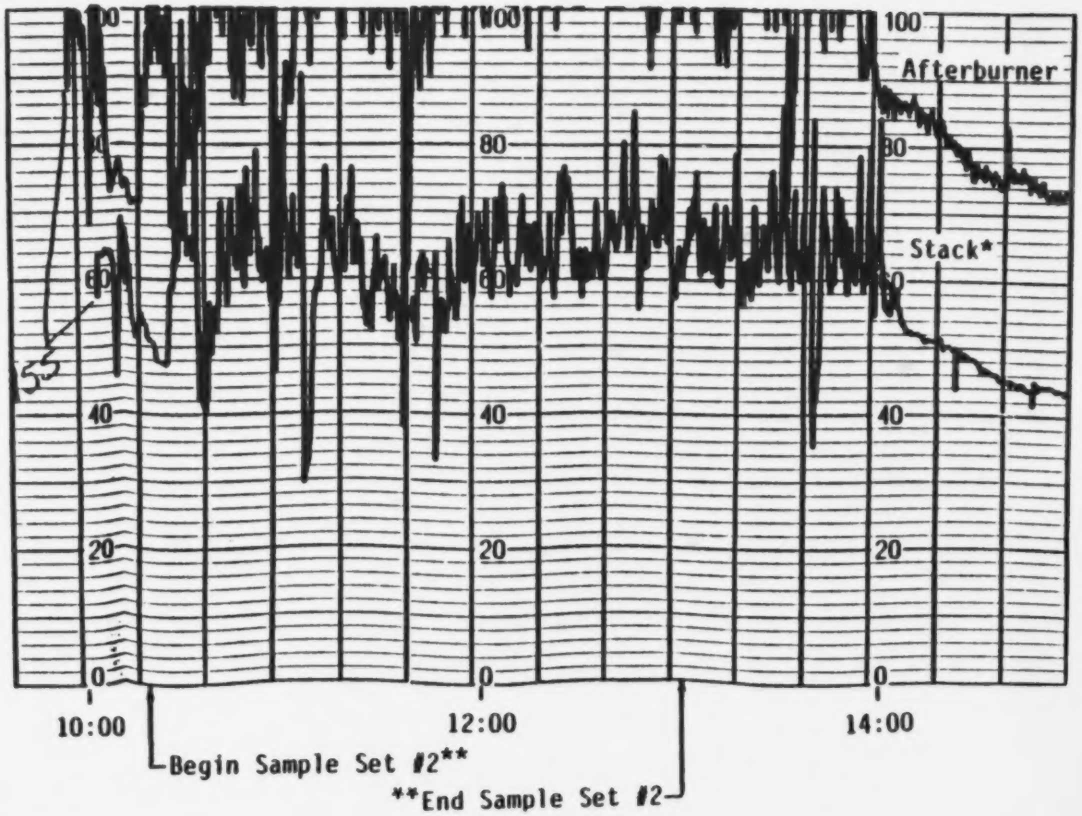

Figure C-10 (Continued)

*Recorder pens were not aligned vertically; thus, stack curve is shifted 8 minutes to the right.

CARBON DIOXIDE EMISSIONS

8/28/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-10% (vol)

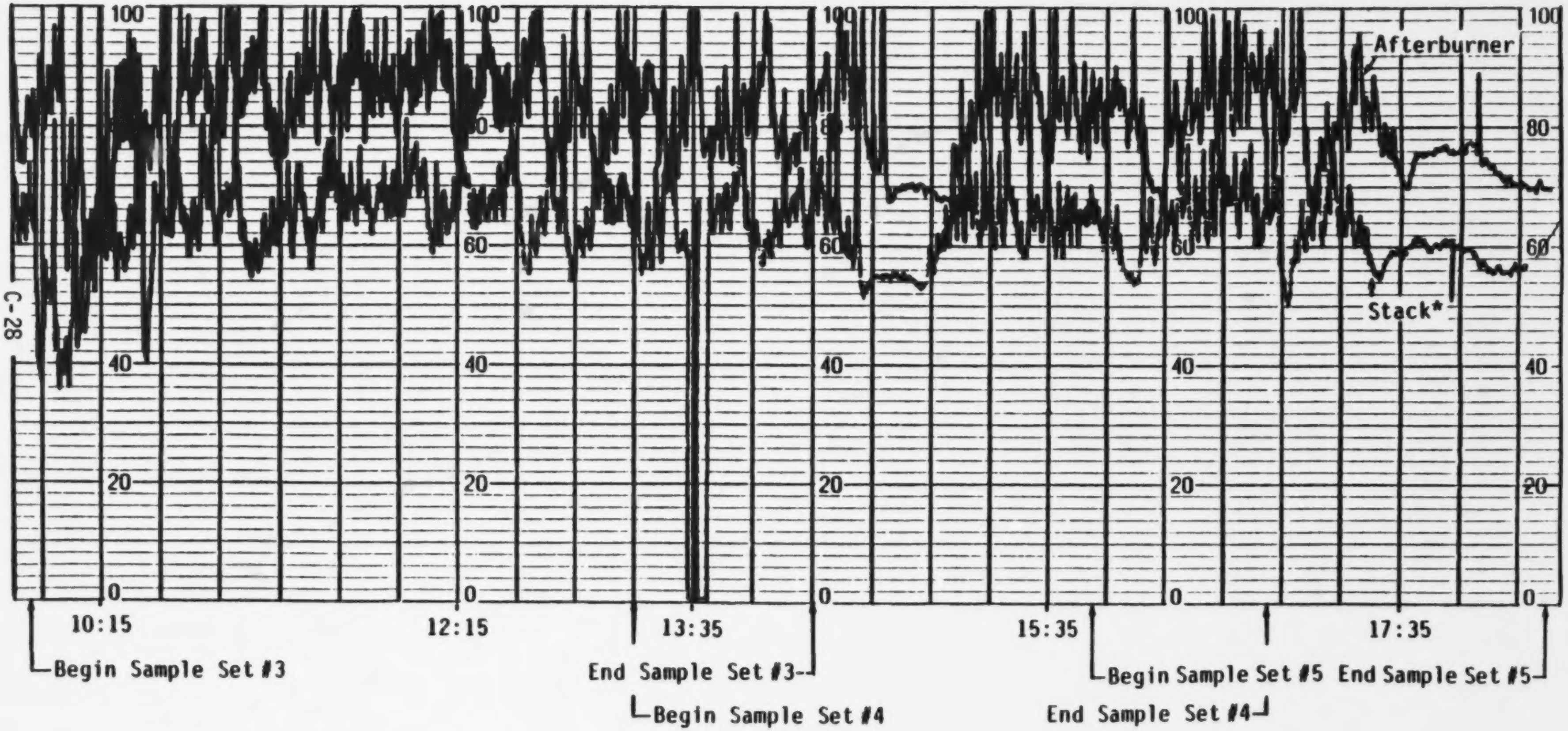

Figure C-11 Carbon Dioxide Emissions for Sample Sets #3, #4, and #5

*Recorder pens were not aligned vertically; thus, stack curve is shifted 8 minutes to the right.

Carbon Monoxide Emissions Strip Charts

CARBON MONOXIDE EMISSIONS
AFTERBURNER
8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-100 ppm

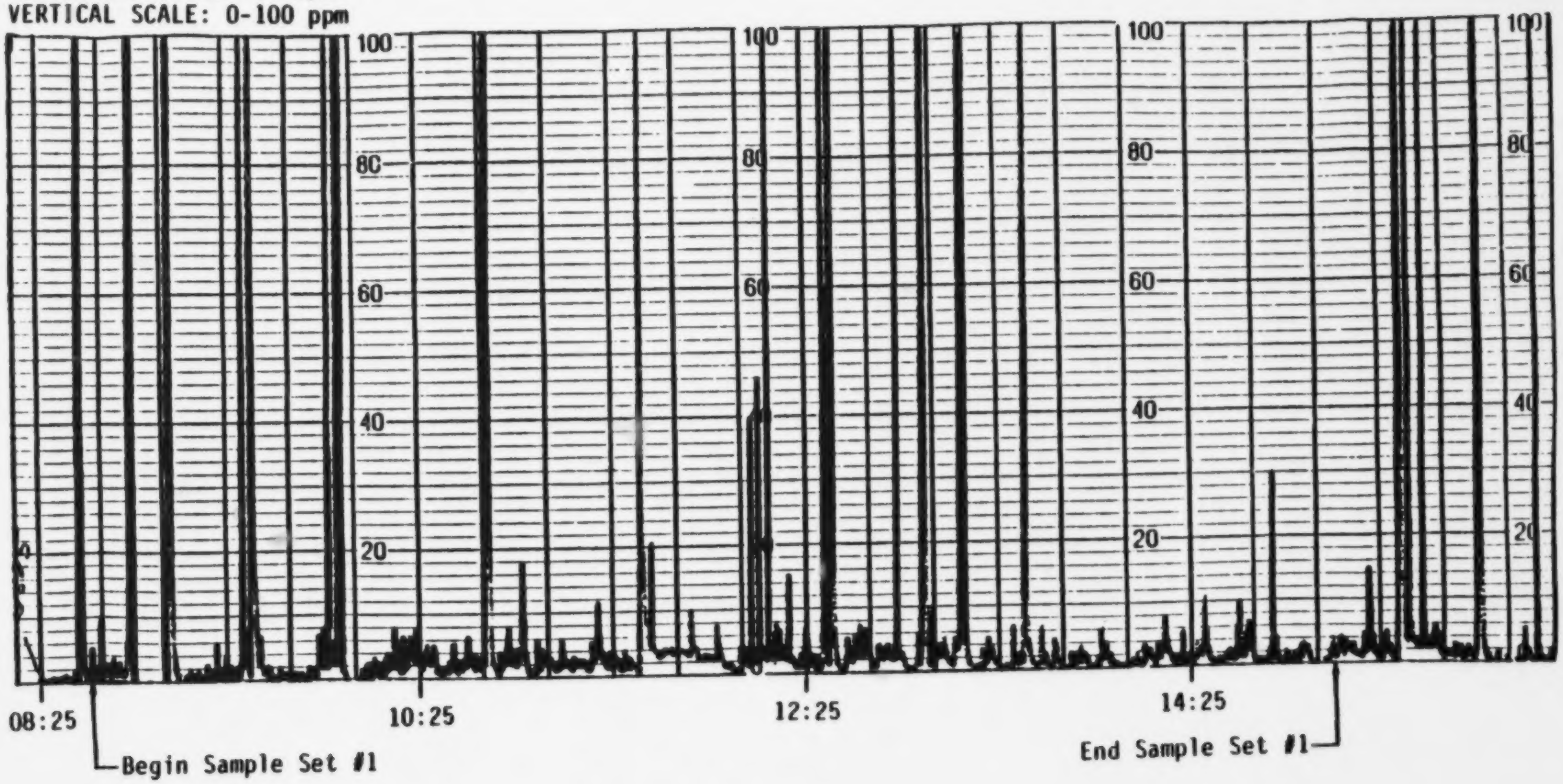

Figure C-12 Carbon Monoxide Emissions for Sample Set #1

CARBON MONOXIDE EMISSIONS
AFTERBURNER
8/25/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-100ppm

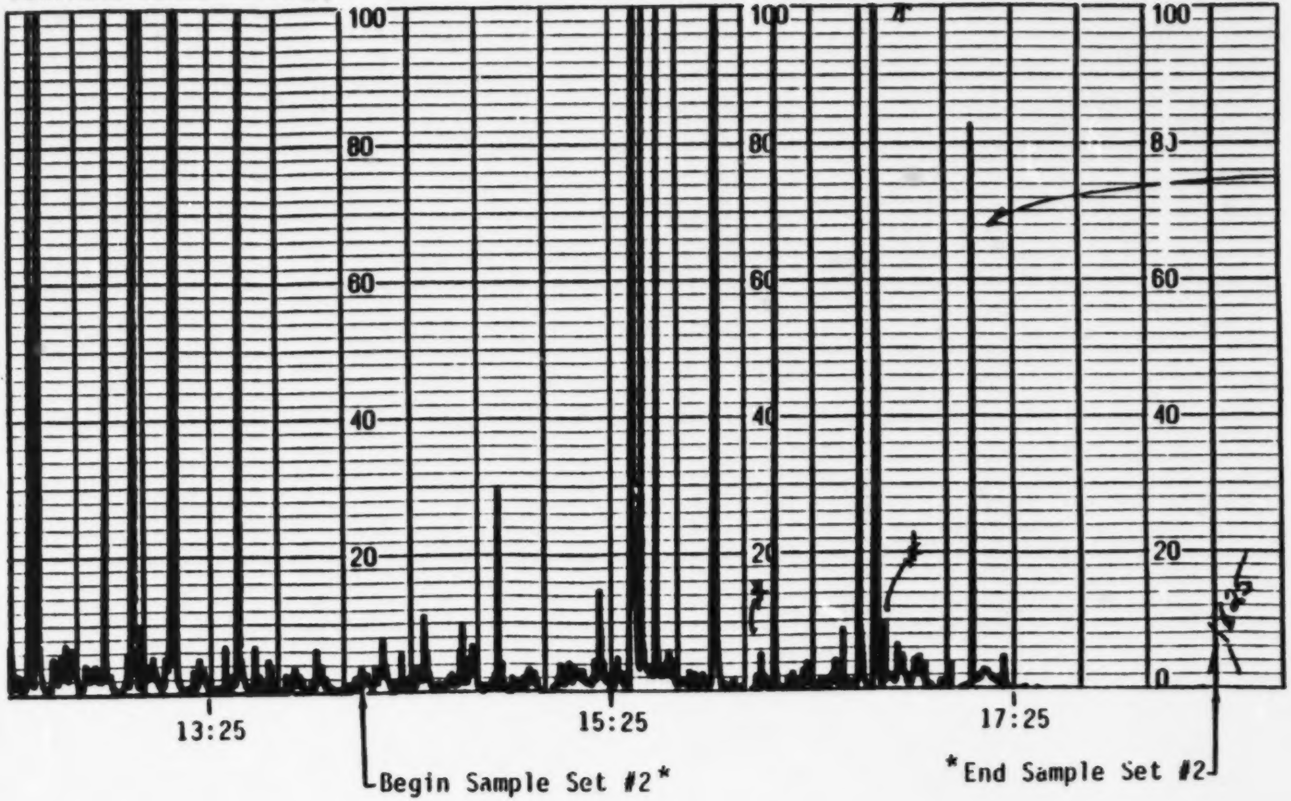

Figure C-13 Carbon Monoxide Emissions for Sample Set #2

CARBON MONOXIDE EMISSIONS
AFTERBURNER
8/26/87
HORIZONTAL SCALE: 3 cm/hr
VERTICAL SCALE: 0-100 ppm

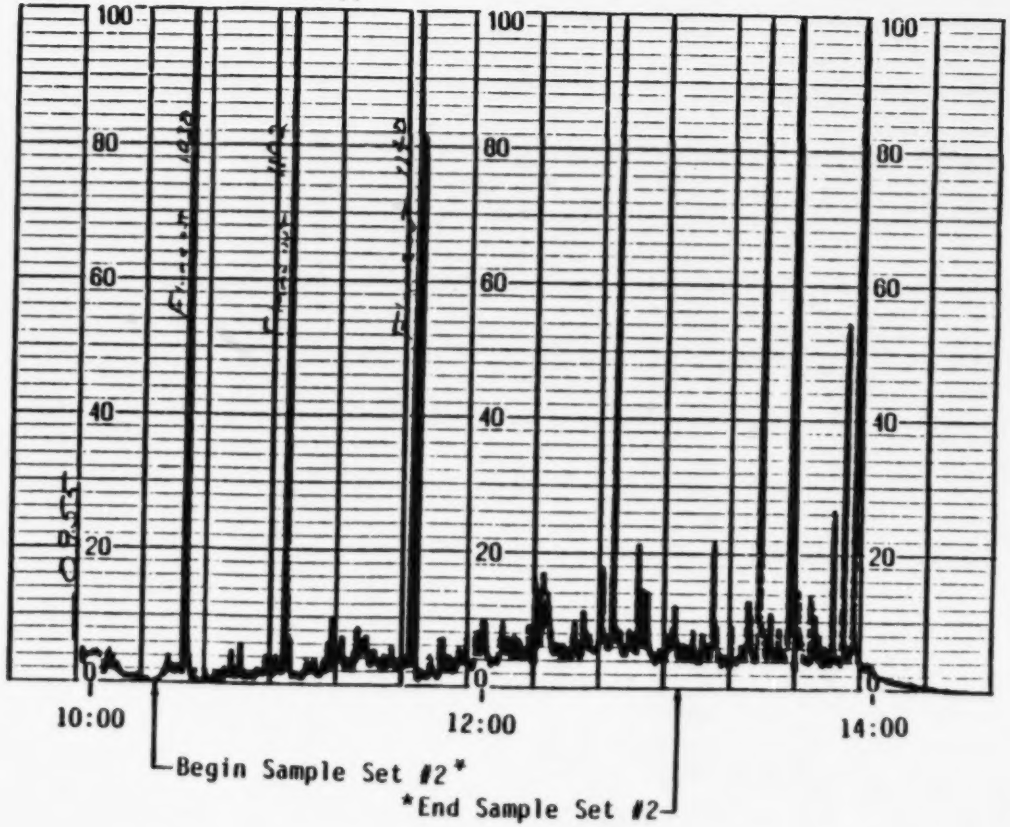

Figure C-13 (Continued)

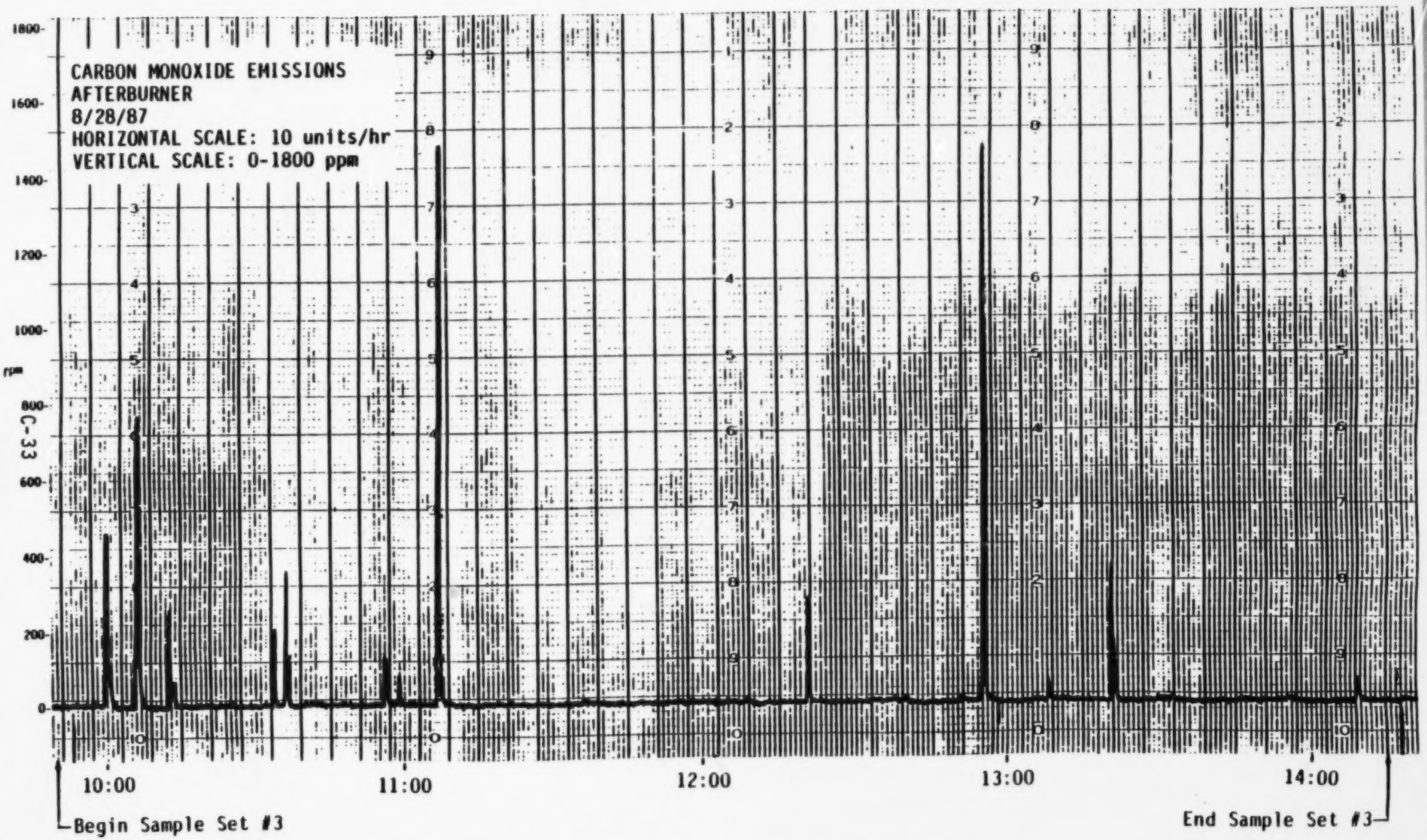

Figure C-14 Carbon Monoxide Emissions for Sample Set #3

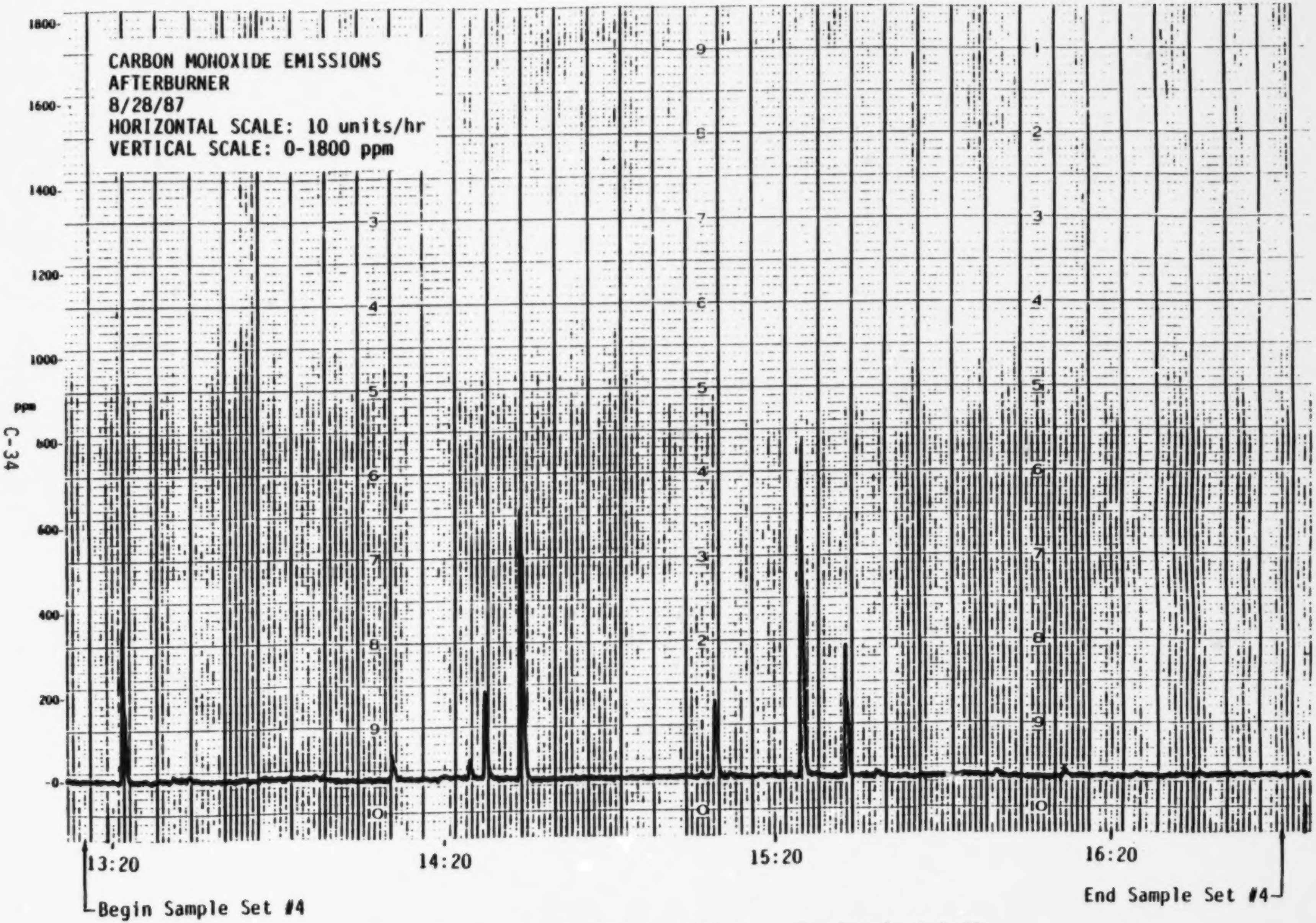

Figure C-15 Carbon Monoxide Emissions for Sample Set #4

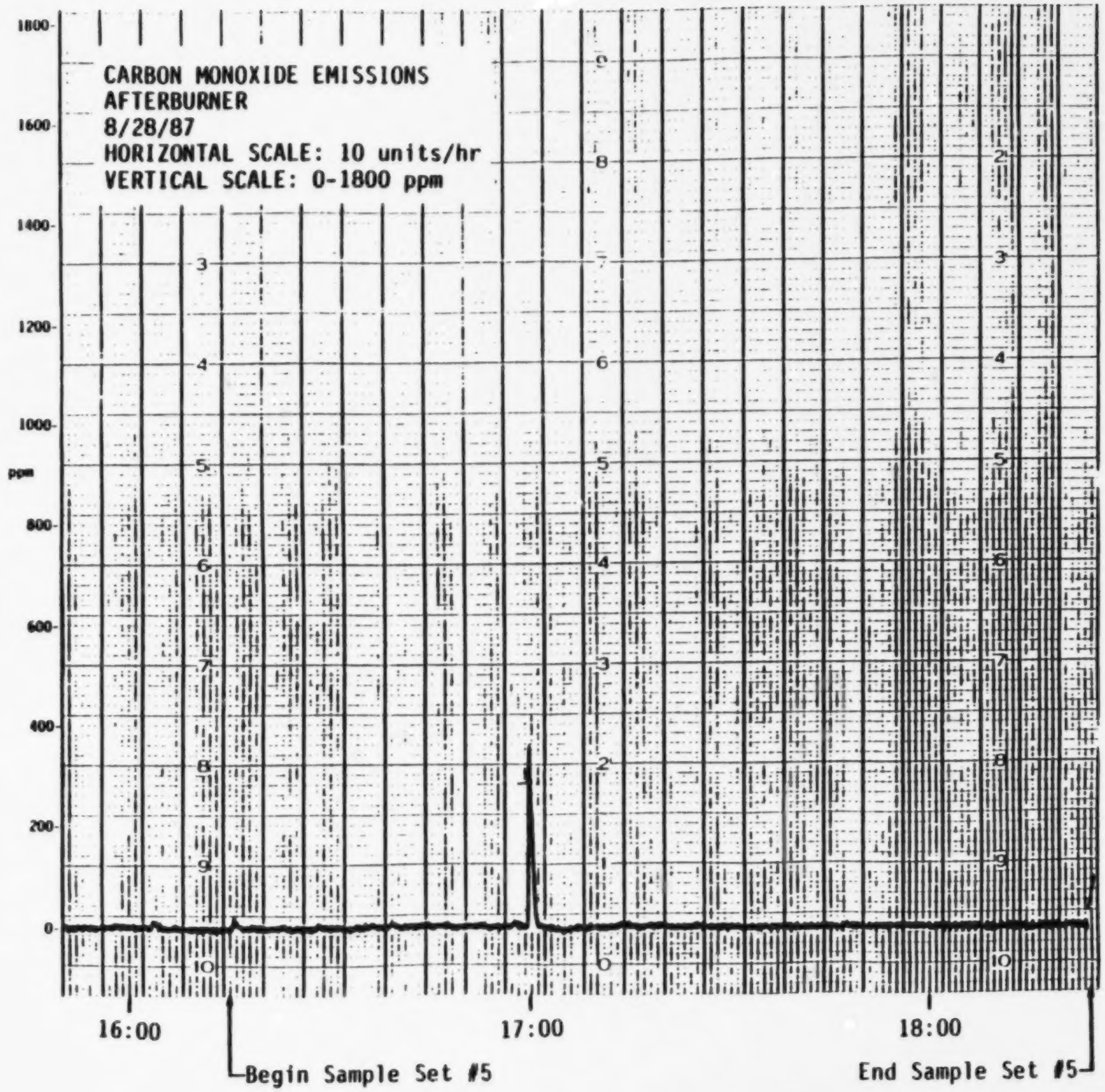

Figure C-16 Carbon Monoxide Emissions for Sample Set #5

APPENDIX D

DETECTION LIMIT TABLES FOR ROTARY KILN INCINERATION PERFORMANCE DATA

Tables D-1 through D-3 indicate detection limits for all constituents analyzed in samples from the K087 rotary kiln incineration test burn.

Table D-1 Detection Limits for Samples of K087 Untreated Waste Collected During the K087 Test Burn

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Volatile Organics (mg/kg)					
Acetone	2.0	2.1	2.0	10.0	10.0
Acetonitrile	20.0	21.0	20.0	104.0	102.0
Acrolein	20.0	21.0	20.0	104.0	102.0
Acrylonitrile	20.0	21.0	20.0	104.0	102.0
Benzene	1.0	1.0	1.0	5.2	5.1
Bromodichloromethane	1.0	1.0	1.0	5.2	5.1
Bromomethane	2.0	2.1	2.0	10.0	10.0
Carbon tetrachloride	1.0	1.0	1.0	5.2	5.1
Carbon disulfide	1.0	1.0	1.0	5.2	5.1
Chlorobenzene	1.0	1.0	1.0	5.2	5.1
2-Chloro-1,3-butadiene	20.0	21.0	20.0	104.0	102.0
Chlorodibromomethane	1.0	1.0	1.0	5.2	5.1
Chloroethane	2.0	2.1	2.0	10.0	10.0
2-Chloroethyl vinyl ether	2.0	2.1	2.0	10.0	10.0
Chloroform	1.0	1.0	1.0	5.2	5.1
Chloromethane	2.0	2.1	2.0	10.0	10.0
3-Chloropropene	20.0	21.0	20.0	104.0	102.0
1,2-Dibromo-3-chloropropane	2.0	2.1	2.0	10.0	10.0
1,2-Dibromomethane	1.0	1.0	1.0	5.2	5.1
Dibromomethane	1.0	1.0	1.0	5.2	5.1
trans-1,4-Dichloro-2-butene	20.0	21.0	20.0	104.0	102.0
Dichlorodifluoromethane	2.0	2.1	2.0	10.0	10.0
1,1-Dichloroethane	1.0	1.0	1.0	5.2	5.1
1,2-Dichloroethane	1.0	1.0	1.0	5.2	5.1
1,1-Dichloroethylene	1.0	1.0	1.0	5.2	5.1
trans-1,2-Dichloroethene	1.0	1.0	1.0	5.2	5.1
1,2-Dichloropropane	1.0	1.0	1.0	5.2	5.1
trans-1,3-Dichloropropene	1.0	1.0	1.0	5.2	5.1
cis-1,3-Dichloropropene	1.0	1.0	1.0	5.2	5.1
1,4-Dioxane	41.0	41.0	41.0	207.0	203.0
Ethyl benzene	1.0	1.0	1.0	5.2	5.1
Ethyl cyanide	20.0	21.0	20.0	104.0	102.0
Ethyl methacrylate	20.0	21.0	20.0	104.0	102.0
Ethylene oxide	82.0	82.0	82.0	414.0	406.0
Iodomethane	10.0	10.0	10.0	5.2	5.1
Isobutyl alcohol	41.0	41.0	41.0	207.0	203.0
Methyl ethyl ketone	2.0	2.1	2.0	10.0	10.0
Methyl isobutyl ketone	2.0	2.1	2.0	10.0	10.0
Methyl methacrylate	20.0	21.0	20.0	104.0	102.0
Methylacrylonitrile	20.0	21.0	20.0	104.0	102.0
Methylene chloride	2.0	1.0	1.0	5.2	5.1
Pyridine	82.0	82.0	82.0	414.0	406.0
1,1,1,2-Tetrachloroethane	1.0	1.0	1.0	5.2	5.1

Table D-1 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Volatile Organics (mg/kg) (continued)					
1,1,2,2-Tetrachloroethane	1.0	1.0	1.0	5.2	5.1
Tetrachloroethene	1.0	1.0	1.0	5.2	5.1
Toluene	1.0	1.0	1.0	5.2	5.1
Tribromomethane	1.0	1.0	1.0	5.2	5.1
1,1,1-Trichloroethane	1.0	1.0	1.0	5.2	5.1
1,1,2-Trichloroethane	1.0	1.0	1.0	5.2	5.1
Trichloroethene	1.0	1.0	1.0	5.2	5.1
Trichloromonofluoromethane	1.0	1.0	1.0	5.2	5.1
1,2,3-Trichloropropane	1.0	1.0	1.0	5.2	5.1
Vinyl chloride	2.0	2.1	2.0	10.0	10.0
Xylenes	1.0	1.0	1.0	5.2	5.1
BDAT Semivolatile Organics (mg/kg)					
Acenaphthalene	894	1010	954	982	1026
Acenaphthene	894	1010	954	982	1026
Acetophenone	1788	2020	1908	1964	2052
2-Acetylaminofluorene	1788	2020	1908	1964	2052
4-Aminobiphenyl	1788	2020	1908	1964	2052
Aniline	894	1010	954	982	1026
Anthracene	894	1010	954	982	1026
Aramite					
Benz(a)anthracene	894	1010	954	982	1026
Benzenethiol					
Benzidine	4470	5050	4770	4910	5130
Benzo(a)pyrene	894	1010	954	982	1026
Benzo(b)fluoranthene	894	1010	954	982	1026
Benzo(ghi)perylene	894	1010	954	982	1026
Benzo(k)fluoranthene	894	1010	954	982	1026
p-Benzoquinone					
Bis(2-chloroethoxy)ethane	894	1010	954	982	1026
Bis(2-chloroethyl)ether	894	1010	954	982	1026
Bis(2-chloropropyl)ether	894	1010	954	982	1026
Bis(2-ethylhexyl)phthalate	894	1010	954	982	1026
4-Bromophenyl phenyl ether	894	1010	954	982	1026
Butyl benzyl phthalate	894	1010	954	982	1026
2-sec-Butyl-4,6-dinitrophenol	4470	5050	4770	4910	5130
p-Chloroaniline	894	1010	954	982	1026
Chlorobenzilate					

Table D-1 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Semivolatile Organics (mg/kg) (continued)					
p-Chloro-m-cresol	894	1010	954	982	1026
2-Chloronaphthalene	894	1010	954	982	1026
2-Chlorophenol	894	1010	954	982	1026
3-Chloropropionitrile					
Chrysene	894	1010	954	982	1026
ortho-Cresol	894	1010	954	982	1026
para Cresol	894	1010	954	982	1026
Dibenz(a,h)anthracene	894	1010	954	982	1026
Dibenzo(a,e)pyrene					
Dibenzo(a,i)pyrene					
m-Dichlorobenzene	894	1010	954	982	1026
o-Dichlorobenzene	894	1010	954	982	1026
p-Dichlorobenzene	894	1010	954	982	1026
3,3'-Dichlorobenzidine	1790	2020	1906	1962	2052
2,4-Dichlorophenol	894	1010	954	982	1026
2,6-Dichlorophenol					
Diethyl phthalate	894	1010	954	982	1026
3,3'-Dimethoxybenzidine	894	1010	954	982	1026
p-Dimethylaminoazobenzene	1788	2020	1908	1964	2052
3,3'-Dimethylbenzidine					
2,4-Dimethylphenol	894	1010	954	982	1026
Dimethyl phthalate	894	1010	954	982	1026
Di-n-butyl phthalate	894	1010	954	982	1026
1,4-Dinitrobenzene	4470	5050	4770	4910	5130
4,6-Dinitro-o-cresol	4474	5050	4766	4906	5130
2,4-Dinitrophenol	4474	5050	4766	4906	5130
2,4-Dinitrotoluene	894	1010	954	982	1026
2,6-Dinitrotoluene	894	1010	954	982	1026
Di-n-octyl phthalate	894	1010	954	982	1026
Di-n-octyl phthalate	894	1010	954	982	1026
Diphenylamine/ diphenylnitrosamine	1788	2020	1908	1964	2052
1,2-Diphenylhydrazine	4470	5050	4770	4910	5130
Fluoranthene	894	1010	954	982	1026
Fluorene	894	1010	954	982	1026
Hexachlorobenzene	894	1010	954	982	1026
Hexachlorobutadiene	894	1010	954	982	1026
Hexachlorocyclopentadiene	894	1010	954	982	1026
Hexachloroethane	894	1010	954	982	1026

Table D-1 (Continued)

Constituent/parameter (units)	Detection limit Sample Set #				
	1	2	3	4	5
BDAT Semivolatile Organics (mg/kg) (continued)					
Hexachlorophene					
Hexachloropropene					
Indeno(1,2,3-cd)pyrene	894	1010	954	982	1026
Isosafrole	1788	2020	1908	1964	2052
Methapyrilene					
3-Methylcholanthrene	1788	2020	1908	1964	2052
4,4'-Methylenebis(2-chloroaniline)	1788	2020	1908	1964	2052
Methyl methanesulfonate					
Naphthalene	894	1010	954	982	1026
1,4-Naphthoquinone					
1-Naphthylamine	4470	5050	4770	4910	5130
2-Naphthylamine	4470	5050	4770	4910	5130
p-Nitroaniline	4474	5050	4766	4906	5130
Nitrobenzene	894	1010	954	982	1026
4-Nitrophenol	4474	5050	4766	4906	5130
N-Nitrosodi-n-butylamine					
N-Nitrosodiethylamine					
N-Nitrosodimethylamine	894	1010	954	982	1026
N-Nitrosomethylethylamine	894	1010	954	982	1026
N-Nitrosomorpholine	1788	2020	1908	1964	2052
N-Nitrosopiperidine	894	1010	954	982	1026
N-Nitrosopyrrolidine	4470	5050	4770	4910	5130
5-Nitro-o-toluidine	1788	2020	1908	1964	2052
Pentachlorobenzene					
Pentachloroethane					
Pentachloronitrobenzene	894	1010	954	982	1026
Pentachlorophenol	4474	5050	4766	4906	5130
Phenacetin	1788	2020	1908	1964	2052
Phenanthrene	894	1010	954	982	1026
Phenol	894	1010	954	982	1026
2-Picoline	894	1010	954	982	1026
Pronamide					
Pyrene	894	1010	954	982	1026
Resorcinol					
Safrole	4470	5050	4770	4910	5130
1,2,4,5-Tetrachlorobenzene	1788	2020	1908	1964	2052
2,3,4,6-Tetrachlorophenol					
1,2,4-Trichlorobenzene	894	1010	954	982	1026
2,4,5-Trichlorophenol	4474	5050	4766	4906	5130
2,4,6 Trichlorophenol	894	1010	954	982	1026
Tris(2,3-dibromopropyl)phosphate					

Table D-1 (Continued)

Constituent parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Metals (mg/kg)					
Antimony	2.0	2.0	2.0	2.0	2.0
Arsenic	1.0	1.0	1.0	1.0	1.0
Barium	20	20	20	20	20
Beryllium	0.5	0.5	0.5	0.5	0.5
Cadmium	1.0	1.0	1.0	1.0	1.0
Chromium	2.0	2.0	2.0	2.0	2.0
Copper	2.5	2.5	2.5	2.5	2.5
Lead	1.0	1.0	1.0	1.0	1.0
Mercury	0.05	0.05	0.05	0.05	0.05
Nickel	4.0	4.0	4.0	4.0	4.0
Selenium	0.5	0.5	0.5	0.5	0.5
Silver	5.0	5.0	5.0	5.0	5.0
Thallium	1.0	1.0	1.0	1.0	1.0
Vanadium	5.0	5.0	5.0	5.0	5.0
Zinc	5.0	5.0	5.0	5.0	5.0
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide	0.50	0.50	0.50	0.50	0.50
Fluoride	0.05	-	-	-	0.05
Sulfide	5.0	5.0	5.0	5.0	5.0
BDAT PCBs (μg/kg)					
Aroclor 1016	50	-	-	-	50
Aroclor 1221	50	-	-	-	50
Aroclor 1232	50	-	-	-	50
Aroclor 1242	50	-	-	-	50
Aroclor 1248	50	-	-	-	50
Aroclor 1254	50	-	-	-	50
Aroclor 1260	50	-	-	-	50
BDAT Dioxins/Furans (ppb)					
Hexachlorodibenzo-p-dioxins	-	-	-	-	2.3
Hexachlorodibenzofuran	-	-	-	-	1.9
Pentachlorodibenzo-p-dioxins	-	-	-	-	2.6
Pentachlorodibenzofuran	-	-	-	-	1.9

Table D-1 (Continued)

Constituent/parameter (units)	Detection limit Sample Set #				
	1	2	3	4	5
BDAT Dioxins/Furans (ppb) (continued)					
Tetrachlorodibenzo-p-dioxins	-	-	-	-	1.9
Tetrachlorodibenzofuran	-	-	-	-	1.8
2,3,7,8-Tetrachlorodibenzo-p-dioxin	-	-	-	-	2.1
Non-BDAT Volatile Organics (mg/kg)					
Styrene	1.0	1.0	1.0	5.2	5.1
Non-BDAT Semivolatile Organics (mg/kg)					
Dibenzofuran	894	1010	954	982	10262
2-Methylnaphthalene	894	1010	954	982	1026
Other Parameters					
Total organic halides (mg/kg)	20	20	20	20	20
Total solids (ppm)	10	10	10	10	10

- = Not analyzed.

Note: Detection limit studies have not been completed for constituents that show no detection limit.

Reference: USEPA 1988a.

Table D-2 Detection Limits for K087 Kiln Ash

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Volatile Organics (µg/kg)					
Acetone	50	50	50	50	50
Acetonitrile	500	500	500	500	500
Acrolein	500	500	500	500	500
Acrylonitrile	500	500	500	500	500
Benzene	25	25	25	25	25
Bromodichloromethane	25	25	25	25	25
Bromomethane	50	50	50	50	50
Carbon tetrachloride	25	25	25	25	25
Carbon disulfide	25	25	25	25	25
Chlorobenzene	25	25	25	25	25
2-Chloro-1,3-butadiene	500	500	500	500	500
Chlorodibromomethane	25	25	25	25	25
Chloroethane	50	50	50	50	50
2-Chloroethyl vinyl ether	50	50	50	50	50
Chloroform	25	25	25	25	25
Chloromethane	50	50	50	50	50
3-Chloropropene	500	500	500	500	500
1,2-Dibromo-3-chloropropane	50	50	50	50	50
1,2-Dibromomethane	25	25	25	25	25
Dibromomethane	25	25	25	25	25
trans-1,4-Dichloro-2-butene	500	500	500	500	500
Dichlorodifluoromethane	50	50	50	50	50
1,1-Dichloroethane	25	25	25	25	25
1,2-Dichloroethane	25	25	25	25	25
1,1-Dichloroethylene	25	25	25	25	25
trans-1,2-Dichloroethene	25	25	25	25	25
1,2-Dichloropropane	25	25	25	25	25
trans-1,3-Dichloropropene	25	25	25	25	25
cis-1,3-Dichloropropene	25	25	25	25	25
1,4-Dioxane	1000	1000	1000	1000	1000
Ethyl benzene	25	25	25	25	25
Ethyl cyanide	500	500	500	500	500
Ethyl methacrylate	500	500	500	500	500
Ethylene oxide	2000	2000	2000	2000	2000
Iodomethane	250	250	250	250	250
Isobutyl alcohol	1000	1000	1000	1000	1000
Methyl ethyl ketone	25	25	25	25	25
Methyl isobutyl ketone	25	25	25	25	25
Methyl methacrylate	500	500	500	500	500
Methylacrylonitrile	500	500	500	500	500
Methylene chloride	25	25	25	25	25
Pyridine	2000	2000	2000	2000	2000

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Volatile Organics (µg/kg) (continued)					
1,1,1,2-Tetrachloroethane	25	25	25	25	25
1,1,2,2-Tetrachloroethane	25	25	25	25	25
Tetrachloroethene	25	25	25	25	25
Toluene	25	25	25	25	25
Tribromomethane	25	25	25	25	25
1,1,1-Trichloroethane	25	25	25	25	25
1,1,2-Trichloroethane	25	25	25	25	25
Trichloroethene	25	25	25	25	25
Trichloromonofluoromethane	25	25	25	25	25
1,2,3-Trichloropropane	25	25	25	25	25
Vinyl chloride	50	50	50	50	50
Xylenes	25	25	25	25	25
BDAT Semivolatile Organics (µg/kg)					
Acenaphthalene	1000	1000	1000	1000	1000
Acenaphthene	1000	1000	1000	1000	1000
Acetophenone	2000	2000	2000	2000	2000
2-Acetylaminofluorene	2000	2000	2000	2000	2000
4-Aminobiphenyl	2000	2000	2000	2000	2000
Aniline	1000	1000	1000	1000	1000
Anthracene	1000	1000	1000	1000	1000
Aramite					
Benz(a)anthracene	1000	1000	1000	1000	1000
Benzenethiol					
Benzidine	5000	5000	5000	5000	5000
Benzo(a)pyrene	1000	1000	1000	1000	1000
Benzo(b)fluoranthene	1000	1000	1000	1000	1000
Benzo(ghi)perylene	1000	1000	1000	1000	1000
Benzo(k)fluoranthene	1000	1000	1000	1000	1000
p-Benzoquinone					
Bis(2-chloroethoxy)ethane	1000	1000	1000	1000	1000
Bis(2-chloroethyl)ether	1000	1000	1000	1000	1000
Bis(2-chloropropyl)ether	1000	1000	1000	1000	1000
Bis(2-ethylhexyl)phthalate	1000	1000	1000	1000	1000
4-Bromophenyl phenyl ether	1000	1000	1000	1000	1000
Butyl benzyl phthalate	1000	1000	1000	1000	1000

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	 2	 3	 4	 5
BDAT Semivolatile Organics (µg/kg) (continued)					
2-sec-Butyl-4,6-dinitrophenol	5000	5000	5000	5000	5000
p-Chloroaniline	1000	1000	1000	1000	1000
Chlorobenzilate					
p-Chloro-m-cresol	1000	1000	1000	1000	1000
2-Chloronaphthalene	1000	1000	1000	1000	1000
2-Chlorophenol	1000	1000	1000	1000	1000
3-Chloropropionitrile					
Chrysene	1000	1000	1000	1000	1000
ortho-Cresol	1000	1000	1000	1000	1000
para-Cresol	1000	1000	1000	1000	1000
Dibenz(a,h)anthracene	1000	1000	1000	1000	1000
Dibenzo(a,e)pyrene					
Dibenzo(a,i)pyrene					
m-Dichlorobenzene	1000	1000	1000	1000	1000
o-Dichlorobenzene	1000	1000	1000	1000	1000
p-Dichlorobenzene	1000	1000	1000	1000	1000
3,3'-Dichlorobenzidine	2000	2000	2000	2000	2000
2,4-Dichlorophenol	1000	1000	1000	1000	1000
2,6-Dichlorophenol					
Diethyl phthalate	1000	1000	1000	1000	1000
3,3'-Dimethoxybenzidine	1000	1000	1000	1000	1000
p-Dimethylaminoazobenzene	2000	2000	2000	2000	2000
3,3'-Dimethylbenzidine					
2,4-Dimethylphenol	1000	1000	1000	1000	1000
Dimethyl phthalate	1000	1000	1000	1000	1000
Di-n-butyl phthalate	1000	1000	1000	1000	1000
1,4-Dinitrobenzene	5000	5000	5000	5000	5000
4,6-Dinitro-o-cresol	5000	5000	5000	5000	5000
2,4-Dinitrophenol	5000	5000	5000	5000	5000
2,4-Dinitrotoluene	1000	1000	1000	1000	1000
2,6-Dinitrotoluene	1000	1000	1000	1000	1000
Di-n-octyl phthalate	1000	1000	1000	1000	1000
Di-n-octyl phthalate	1000	1000	1000	1000	1000
Diphenylamine/ diphenylnitrosamine	2000	2000	2000	2000	2000
1,2-Diphenylhydrazine	5000	5000	5000	5000	5000
Fluoranthene	1000	1000	1000	1000	1000
Fluorene	1000	1000	1000	1000	1000

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Semivolatile Organics (μg/kg) (continued)					
Hexachlorobenzene	1000	1000	1000	1000	1000
Hexachlorobutadiene	1000	1000	1000	1000	1000
Hexachlorocyclopentadiene	1000	1000	1000	1000	1000
Hexachloroethane	1000	1000	1000	1000	1000
Hexachlorophene					
Hexachloropropene					
Indeno(1,2,3-cd)pyrene	1000	1000	1000	1000	1000
Isosafrole	2000	2000	2000	2000	2000
Methapyrilene					
3-Methylcholanthrene	2000	2000	2000	2000	2000
4,4'-Methylenebis(2-chloroaniline)	2000	2000	2000	2000	2000
Methyl methanesulfonate					
Naphthalene	1000	1000	1000	1000	1000
1,4-Naphthoquinone					
1-Naphthylamine	5000	5000	5000	5000	5000
2-Naphthylamine	5000	5000	5000	5000	5000
p-Nitroaniline	5000	5000	5000	5000	5000
Nitrobenzene	1000	1000	1000	1000	1000
4-Nitrophenol	5000	5000	5000	5000	5000
N-Nitrosodi-n-butylamine					
N-Nitrosodiethylamine					
N-Nitrosodimethylamine	1000	1000	1000	1000	1000
N-Nitrosomethylethylamine	1000	1000	1000	1000	1000
N-Nitrosomorpholine	2000	2000	2000	2000	2000
N-Nitrosopiperidine	1000	1000	1000	1000	1000
N-Nitrosopyrrolidine	5000	5000	5000	5000	5000
5-Nitro-o-toluidine	2000	2000	2000	2000	2000
Pentachlorobenzene					
Pentachloroethane					
Pentachloronitrobenzene	10000	10000	10000	10000	100001
Pentachlorophenol	5000	5000	5000	5000	5000
Phenacetin	2000	2000	2000	2000	2000
Phenanthrene	1000	1000	1000	1000	1000
Phenol	1000	1000	1000	1000	1000
2-Picoline	1000	1000	1000	1000	1000
Pronamide					
Pyrene	1000	1000	1000	1000	1000
Resorcinol					
Safrole	5000	5000	5000	5000	5000

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT Semivolatile Organics (µg/kg) (continued)					
1,2,4,5-Tetrachlorobenzene	2000	2000	2000	2000	2000
2,3,4,6-Tetrachlorophenol					
1,2,4-Trichlorobenzene	1000	1000	1000	1000	1000
2,4,5-Trichlorophenol	5000	5000	5000	5000	5000
2,4,6-Trichlorophenol	1000	1000	1000	1000	1000
Tris(2,3-dibromopropyl)phosphate					
BDAT Metals Other Than Metals (mg/kg)					
Antimony	3.2	2.0	2.0	2.0	3.2
Arsenic	1.0	1.0	1.0	1.0	1.0
Barium	0.10	20	20	20	0.10
Beryllium	0.10	0.5	0.5	0.5	0.10
Cadmium	0.40	1.0	1.0	1.0	0.40
Chromium	0.70	2.0	2.0	2.0	0.70
Copper	0.60	2.5	2.5	2.5	0.60
Lead	0.50	1.0	1.0	1.0	0.50
Mercury	0.10	0.05	0.05	0.05	0.10
Nickel	1.1	4.0	4.0	4.0	1.1
Selenium	0.50	0.50	0.50	0.50	0.50
Silver	0.60	5.0	5.0	5.0	0.60
Thallium	1.0	1.0	1.0	1.0	1.0
Vanadium	0.60	5.0	5.0	5.0	0.60
Zinc	0.20	2.5	2.5	2.5	0.20
BDAT TCLP Metals (µg/l)					
Antimony	32	20	20	20	32
Arsenic	10	10	10	10	10
Barium	1.0	200	200	200	1.0
Beryllium	1.0	5.0	5.0	5.0	1.0
Cadmium	4.0	10	10	10	4.0
Chromium	7.0	20	20	20	7.0
Copper	6.0	25	25	25	6.0
Lead	5.0	1.0	1.0	1.0	5.0
Mercury	0.20	0.30	0.30	0.30	0.20

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
BDAT TCLP Metals (µg/l) (continued)					
Nickel	11	40	40	40	11
Selenium	50	5.0	5.0	5.0	5.0
Silver	6.0	50	50	50	6.0
Thallium	10	10	10	10	500
Vanadium	6.0	50	50	50	6.0
Zinc	2.0	50	50	50	2.0
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide	0.50	0.50	0.50	0.50	0.50
Fluoride	1.0	-	-	-	1.0
Sulfide	5.0	5.0	5.0	5.0	2.5
BDAT PCBs (µg/kg)					
Aroclor 1016	50	-	-	-	50
Aroclor 1221	50	-	-	-	50
Aroclor 1232	50	-	-	-	50
Aroclor 1242	50	-	-	-	50
Aroclor 1248	50	-	-	-	50
Aroclor 1254	50	-	-	-	50
Aroclor 1260	50	-	-	-	50
BDAT Dioxins/Furans (ppb)					
Hexachlorodibenzo-p-dioxins	-	-	-	-	0.09
Hexachlorodibenzofuran	-	-	-	-	0.02
Pentachlorodibenzo-p-dioxins	-	-	-	-	0.07
Pentachlorodibenzofuran	-	-	-	-	0.04
Tetrachlorodibenzo-p-dioxins	-	-	-	-	0.02
Tetrachlorodibenzofuran	-	-	-	-	0.02
2,3,7,8-Tetrachlorodibenzo-p-dioxin	-	-	-	-	0.01

Table D-2 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5
Non-BDAT Volatile Organics (µg/kg)					
Styrene	25	25	25	25	25
Non-BDAT Semivolatile Organics (µg/kg)					
Dibenzofuran	1000	1000	1000	1000	1000
2-Methylnaphthalene	1000	1000	1000	1000	1000
Other Parameters					
Total organic carbon (mg/kg)	200	200	200	200	200
Total chlorides (mg/kg)	5.0	5.0	5.0	5.0	5.0
Total organic halides (mg/kg)	10	10	10	10	10

- = Not analyzed.

Note: Detection limit studies have not been completed for constituents that show no detection limit.

Reference: USEPA 1988a.

Table D-3 Detection Limits for K087 Scrubber Effluent Water

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5	6
BDAT Volatile Organics (µg/l)						
Acetone	10	10	10	10	10	10
Acetonitrile	100	100	100	100	100	100
Acrolein	100	100	100	100	100	100
Acrylonitrile	100	100	100	100	100	100
Benzene	5	5	5	5	5	5
Bromodichloromethane	5	5	5	5	5	5
Bromomethane	10	10	10	10	10	10
n-Butyl alcohol						
Carbon tetrachloride	5	5	5	5	5	5
Carbon disulfide	5	5	5	5	5	5
Chlorobenzene	5	5	5	5	5	5
2-Chloro-1,3-butadiene	100	100	100	100	100	100
Chlorodibromomethane	5	5	5	5	5	5
Chloroethane	10	10	10	10	10	10
2-Chloroethyl vinyl ether	10	10	10	10	10	10
Chloroform	5	5	5	5	5	5
Chloromethane	10	10	10	10	10	10
3-Chloropropene	100	100	100	100	100	100
1,2-Dibromo-3-chloropropane	10	10	10	10	10	10
1,2-Dibromomethane	5	5	5	5	5	5
Dibromomethane	5	5	5	5	5	5
trans-1,4-Dichloro-2-butene	100	100	100	100	100	100
Dichlorodifluoromethane	10	10	10	10	10	10
1,1-Dichloroethane	5	5	5	5	5	5
1,2-Dichloroethane	5	5	5	5	5	5
1,1-Dichloroethylene	5	5	5	5	5	5
trans-1,2-Dichloroethene	5	5	5	5	5	5
1,2-Dichloropropane	5	5	5	5	5	5
trans-1,3-Dichloropropene	5	5	5	5	5	5
cis-1,3-Dichloropropene	5	5	5	5	5	5
1,4-Dioxane	200	200	200	200	200	200
Ethyl benzene	5	5	5	5	5	5
Ethyl cyanide	100	100	100	100	100	100
Ethyl methacrylate	100	100	100	100	100	100
Ethylene oxide						
Iodomethane	50	50	50	50	50	50
Isobutyl alcohol	200	200	200	200	200	200
Methyl ethyl ketone	10	10	10	10	10	10
Methyl isobutyl ketone						
Methyl methacrylate	100	100	100	100	100	100
Methylacrylonitrile	100	100	100	100	100	100
Methylene chloride	5	5	5	5	5	5
Pyridine	400	400	400	400	400	400
1,1,1,2-Tetrachloroethane	5	5	5	5	5	5

Table D-3 (Continued)

Constituent/parameter (units)	Detection limit Sample Set #					
	1	2	3	4	5	6
BDAT Volatile Organics (µg/l) (continued)						
1,1,2,2-Tetrachloroethane	5	5	5	5	5	5
Tetrachloroethene	5	5	5	5	5	5
Toluene	5	5	5	5	5	5
Tribromomethane	5	5	5	5	5	5
1,1,1-Trichloroethane	5	5	5	5	5	5
1,1,2-Trichloroethane	5	5	5	5	5	5
Trichloroethene	5	5	5	5	5	5
Trichloromonofluoromethane	5	5	5	5	5	5
1,2,3-Trichloropropane	5	5	5	5	5	5
Vinyl chloride	10	10	10	10	10	10
Xylenes	5	5	5	5	5	5
BDAT Semivolatile Organics (µg/l)						
Acenaphthalene	10	10	10	10	10	10
Acenaphthene	10	10	10	10	10	10
Acetophenone	10	10	10	10	10	10
2-Acetylaminofluorene	10	10	10	10	10	10
4-Aminobiphenyl	50	50	50	50	50	50
Aniline	10	10	10	10	10	10
Anthracene						
Aramite	50	50	50	50	50	50
Benz(a)anthracene	10	10	10	10	10	10
Benzenethiol						
Benzidine	100	100	100	100	100	100
Benzo(a)pyrene	10	10	10	10	10	10
Benzo(b)fluoranthene	50	50	50	50	50	50
Benzo(ghi)perylene	10	10	10	10	10	10
Benzo(k)fluoranthene	10	10	10	10	10	10
p-Benzoquinone	20	20	20	20	20	20
Bis(2-chloroethoxy)ethane	10	10	10	10	10	10
Bis(2-chloroethyl)ether	10	10	10	10	10	10
Bis(2-chloropropyl)ether						
Bis(2-ethylhexyl)phthalate	10	10	10	10	10	10
4-Bromophenyl phenyl ether	10	10	10	10	10	10
Butyl benzyl phthalate						
2-sec-Butyl-4,6-dinitrophenol						
p-Chloroaniline	10	10	10	10	10	10
Chlorobenzilate	10	10	10	10	10	10
p-Chloro-m-cresol	10	10	10	10	10	10
2-Chloronaphthalene	10	10	10	10	10	10

Table D-3 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5	6
BDAT Semivolatile Organics (μg/l) (continued)						
2-Chlorophenol	20	20	20	20	20	20
3-Chloropropionitrile	10	10	10	10	10	10
Chrysene	50	50	50	50	50	50
ortho-Cresol	10	10	10	10	10	10
para-Cresol	10	10	10	10	10	10
Dibenz(a,h)anthracene	10	10	10	10	10	10
Dibenzo(a,e)pyrene	50	50	50	50	50	50
Dibenzo(a,i)pyrene	10	10	10	10	10	10
m-Dichlorobenzene	20	20	20	20	20	20
o-Dichlorobenzene	10	10	10	10	10	10
p-Dichlorobenzene	20	20	20	20	20	20
3,3'-Dichlorobenzidine	10	10	10	10	10	10
2,4-Dichlorophenol	10	10	10	10	10	10
2,6-Dichlorophenol	20	20	20	20	20	20
Diethyl phthalate	10	10	10	10	10	10
3,3'-Dimethoxybenzidine						
p-Dimethylaminoazobenzene	20	20	20	20	20	20
3,3'-Dimethylbenzidine	10	10	10	10	10	10
2,4-Dimethylphenol	10	10	10	10	10	10
Dimethyl phthalate						
Di-n-butyl phthalate	10	10	10	10	10	10
1,4-Dinitrobenzene	50	50	50	50	50	50
4,6-Dinitro-o-cresol						
2,4-Dinitrophenol	10	10	10	10	10	10
2,4-Dinitrotoluene	10	10	10	10	10	10
2,6-Dinitrotoluene	10	10	10	10	10	10
Di-n-octyl phthalate	50	50	50	50	50	50
Diphenylamine/ diphenylnitrosamine	10	10	10	10	10	10
1,2-Diphenylhydrazine	20	20	20	20	20	20
Fluoranthene	10	10	10	10	10	10
Fluorene	10	10	10	10	10	10
Hexachlorobenzene	10	10	10	10	10	10
Hexachlorobutadiene	10	10	10	10	10	10
Hexachlorocyclopentadiene	10	10	10	10	10	10
Hexachloroethane	50	50	50	50	50	50
Hexachlorophene						
Hexachloropropene						
Indeno(1,2,3-cd)pyrene	10	10	10	10	10	10

Table D-3 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	 2	 3	 4	 5	 6
BDAT Semivolatile Organics (μg/l) (continued)						
Isosafrole	50	50	50	50	50	50
Methapyrilene	10	10	10	10	10	10
3-Methylcholanthrene						
4,4'-Methylenebis(2-chloroaniline)	10	10	10	10	10	10
Methyl methanesulfonate						
Naphthalene	10	10	10	10	10	10
1,4-Naphthoquinone	50	50	50	50	50	50
1-Naphthylamine						
2-Naphthylamine	50	50	50	50	50	50
p-Nitroaniline						
Nitrobenzene	10	10	10	10	10	10
4-Nitrophenol						
N-Nitrosodi-n-butylamine	20	20	20	20	20	20
N-Nitrosodiethylamine	10	10	10	10	10	10
N-Nitrosodimethylamine	20	20	20	20	20	20
N-Nitrosomethylethylamine	10	10	10	10	10	10
N-Nitrosomorpholine						
N-Nitrosopiperidine	10	10	10	10	10	10
N-Nitrosopyrrolidine						
5-Nitro-o-toluidine	10	10	10	10	10	10
Pentachlorobenzene	10	10	10	10	10	10
Pentachloroethane	10	10	10	10	10	10
Pentachloronitrobenzene						
Pentachlorophenol	20	20	20	20	20	20
Phenacetin	10	10	10	10	10	10
Phenanthrene	10	10	10	10	10	10
Phenol	10	10	10	10	10	10
2-Picoline	50	50	50	50	50	50
Pronamide	20	20	20	20	20	20
Pyrene	20	20	20	20	20	20
Resorcinol	20	20	20	20	20	20
Safrole	10	10	10	10	10	10
1,2,4,5-Tetrachlorobenzene						
2,3,4,6-Tetrachlorophenol						
1,2,4-Trichlorobenzene						
2,4,5-Trichlorophenol	50	50	50	50	50	50
2,4,6-Trichlorophenol	10	10	10	10	10	10
Tris(2,3-dibromopropyl)phosphate						

Table D-3 (Continued)

Constituent/parameter (units)	Detection limit Sample Set # 1	2	3	4	5	6
BDAT Metals (ug/l)						
Antimony	32	33	20	20	20	32
Arsenic	10	10	10	10	10	10
Barium	1.0	1.0	200	200	200	1.0
Beryllium	1.0	1.0	5.0	5.0	5.0	1.0
Cadmium	4.0	4.0	10	10	10	4.0
Chromium	7.0	7.0	20	20	20	7.0
Copper	6.0	6.0	25	25	25	6.0
Lead	5.0	5.0	10	10	10	5.5
Mercury	0.20	0.20	0.30	0.30	0.30	0.20
Nickel	11	11	40	40	40	11
Selenium	5.0	5.0	5.0	5.0	5.0	5.0
Silver	6.0	7.0	50	50	50	6.0
Thallium	10	10	10	10	10	10
Vanadium	6.0	6.0	50	50	50	6.0
Zinc	2.0	2.0	50	50	50	2.0
BDAT Inorganics Other Than Metals (mg/l)						
Cyanide	0.01	0.01	0.01	0.01	0.01	0.01
Fluoride	0.20	0.20	0.01	-	-	0.20
Sulfide	1.0	1.0	1.0	1.0	1.0	1.0
BDAT PCBs (μg/l)						
Aroclor 1016	-	-	-	-	-	0.5
Aroclor 1221	-	-	-	-	-	0.5
Aroclor 1232	-	-	-	-	-	0.5
Aroclor 1242	-	-	-	-	-	0.5
Aroclor 1248	-	-	-	-	-	0.5
Aroclor 1254	-	-	-	-	-	1.0
Aroclor 1260	-	-	-	-	-	1.0
BDAT Dioxins/Furans (ppt)						
Hexachlorodibenzo-p-dioxins	-	-	-	-	-	0.39
Hexachlorodibenzofuran	-	-	-	-	-	0.32
Pentachlorodibenzo-p-dioxins	-	-	-	-	-	1.45
Pentachlorodibenzofuran	-	-	-	-	-	0.75
Tetrachlorodibenzo-p-dioxins	-	-	-	-	-	0.32
Tetrachlorodibenzofuran	-	-	-	-	-	0.32
2,3,7,8-Tetrachlorodibenzo-p-dioxin	-	-	-	-	-	0.32

Table D-3 (Continued)

	Detection limit Sample Set [a]					
Constituent/parameter (units)	1	2	3	4	5	6
Non-BDAT Volatile Organics (μg/l)						
Styrene	5	5	5	5	5	5
Non-BDAT Semivolatile Organics (μg/l)						
Dibenzofuran	10	10	10	10	10	10
2-Methylnaphthalene	10	10	10	10	10	10
Other Parameters						
Total chlorides (mg/l)	1.0	1.0	1.0	1.0	1.0	1.0
Total organic carbon (mg/l)	2.0	2.0	2.0	2.0	2.0	2.0
Total organic halides (μg/l)	10	10	10	10	10	20
Total solids (mg/l)	10	10	10	10	10	10

Reference: USEPA 1988a.

[a] Samples are not assigned to sample sets.

- = Not analyzed.

Note: Detection limit studies have not been completed for constituents that show no detection limit.

APPENDIX E

METHOD OF MEASUREMENT FOR THERMAL CONDUCTIVITY

The comparative method of measuring thermal conductivity has been proposed as an ASTM test method under the name "Guarded, Comparative, Longitudinal Heat Flow Technique." A thermal heat flow circuit is used that is the analog of an electrical circuit with resistances in series. A reference material is chosen to have a thermal conductivity close to that estimated for the sample. Reference standards (also known as heat meters) having the same cross-sectional dimensions as the sample are placed above and below the sample. An upper heater, a lower heater, and a heat sink are added to the "stack" to complete the heat flow circuit. See Figure E-1.

The temperature gradients (analogous to potential differences) along the stack are measured with type K (chromel/alumel) thermocouples placed at known separations. The thermocouples are placed into holes or grooves in the references and also in the sample whenever the sample is thick enough to accommodate them.

For molten samples, pastes, greases, and other materials that must be contained, the material is placed into a cell consisting of a top and bottom of Pyrex 7740 and a containment ring of marinite. The sample is 2 inches in diameter and 0.5 inch thick. Thermocouples are not placed into the sample; rather, the temperatures measured in the Pyrex are extrapolated to give the temperature at the top and bottom surfaces of the sample material. The Pyrex disks also serve as the thermal conductivity reference material.

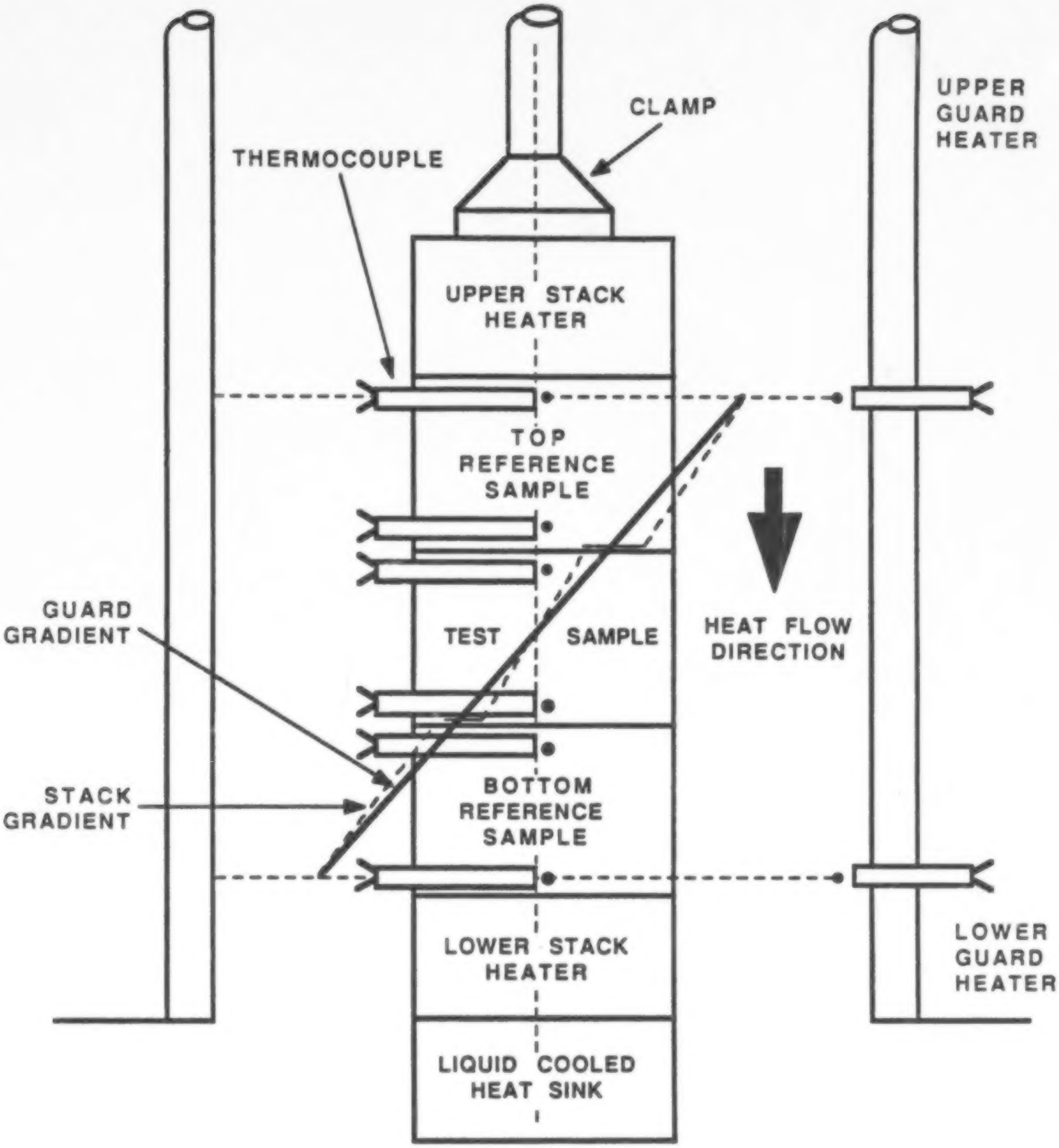
UPPER GUARD HEATER
CLAMP
THERMOCOUPLE
UPPER STACK HEATER
TOP REFERENCE SAMPLE
GUARD GRADIENT
TEST SAMPLE
HEAT FLOW DIRECTION
STACK GRADIENT
BOTTOM REFERENCE SAMPLE
LOWER STACK HEATER
LOWER GUARD HEATER
LIQUID COOLED HEAT SINK

FIGURE E-1 SCHEMATIC DIAGRAM OF THE COMPARATIVE METHOD

The stack is clamped with a reproducible load to ensure intimate contact between the components. To produce a linear flow of heat down the stack and reduce the amount of heat that flows radially, a guard tube is placed around the stack, and the intervening space is filled with insulating grains or powder. The temperature gradient in the guard is matched to that in the stack to further reduce radial heat flow.

The comparative method is a steady-state method of measuring thermal conductivity. When equilibrium is reached, the heat flux (analogous to current flow) down the stack can be determined from the references. The heat into the sample is given by

$$Q_{in} = \lambda_{top} (dT/dx)_{top}$$

and the heat out of the sample is given by

$$Q_{out} = \lambda_{bottom} (dT/dx)_{bottom}$$

where

λ = thermal conductivity

dT/dx = temperature gradient

and top refers to the upper reference, while bottom refers to the lower reference. If the heat were confined to flow down the stack, then Q_{in} and Q_{out} would be equal. If Q_{in} and Q_{out} are in reasonable agreement, the average heat flow is calculated from

$$Q = (Q_{in} + Q_{out})/2.$$

The sample thermal conductivity is then found from

$$\lambda_{sample} = Q/(dT/dx)_{sample}.$$